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RECENT IMPROVEMENTS IN THE COMPASS, WITH CORRECTORS FOR IRON SHIPS.

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From the "Journal of the Royal United Service Institution."

THE improvements which I have made in my compass since the date of my first communication to the Royal United Service Institution (February 4, 1878) have had for a primary object to obtain greater steadiness of the compass in vessels of war during gun-fire, and in steamers generally in which there is great vibration, due to the working of the engines, screw, or other causes. Improvements of some importance have also been made in the system of magnetic correctors for the semicircular and heeling errors, and in the addition of an adjustable Flinders bar for the automatic correction of that part of the semicircular error, which depends on magnetization of the ship by the vertical component of the terrestrial magnetic force at the ship's place. I have also made an improved dipping needle instrument which is much less cumbrous and at the same time more sensitive and more easily used than the marine dipping needle which I described in my former communication.*

In my present communication I shall first describe the mechanical improvements, and then go on to explain their application for keeping the compass as nearly correct as may be for practical use at sea.

To produce such steadiness of the compass-card as has hitherto been obtained in steamers which have powerful engines, and where there is much vibration, it has been customary to suspend the bowl by means of india-rubber bands. A serious objection to this method is that the india-rubber is liable to become rotten by exposure to heat or oil, especially if it is used in fine enough bands to give the requisite steadiness in all circumstances. After many trials of metallic springs in lieu of the india-rubber, I at last found a plan of brass spring resembling a rope grummet (A, Figs. 1, 2, 3, 4, 5, 6), but with elastic brass wire instead of the rope strands, by which I succeeded in obtaining more satisfactory steadiness of the compass than with india-rubber. The construction of this brass grummet-ring and the mounting of the compass-bowl upon it, may be described as follows:—A single wire is first bent and its ends are united by soldering or brazing, so as to form a ring of the proper size. This serves as a core on which a second brass wire is laid on spirally, six turns round the core (Fig. 6). The ends of this second wire are also united by soldering or brazing, and thus an elastic ring is produced strong enough to support the compass-bowl. The compass-bowl is

* See Journal, vol. xxii., No. XCIV., p. 91, *et seq.*

suspended from the elastic ring with the intervention of a rigid gimbal ring. The elastic ring has two sockets fixed at the ends of a diameter, which rest on two balls attached to the brass rim of the binnacle stand (Figs. 2 and 4). The elasticity of the ring mitigates the effect on the knife-edges bearing the gimbal ring and bowl, and on the point bearing the compass-card, of vertical tremors of the platform on which the binnacle rests. The knife-edges of the gimbal ring are supported on two grooved stirrups, hung

Fig. 1

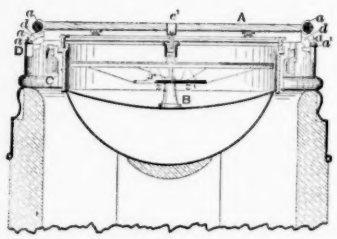
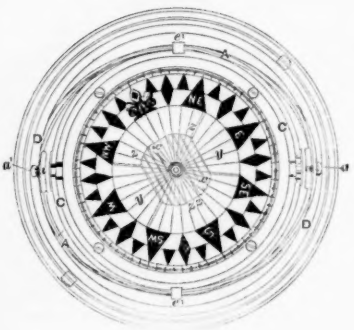


Fig. 2



by chains from the elastic rings (Figs. 5 and 6). This suspension mitigates the effect of horizontal tremors of the platform.

Figs. 1, 2, 3, 4, 5, 6 illustrate the suspension of the bowl from the elastic ring.

For ascertaining the heeling error I use an auxiliary instrument for comparing the vertical component of the earth's magnetic force on shore with the vertical component on board ship. This instrument is constructed as follows:—Two magnetic needles of hardened steel wire are joined together and supported on two iridium points in a line at right angles to the lengths of the needles, and passing as nearly as may be through the center

Fig. 3

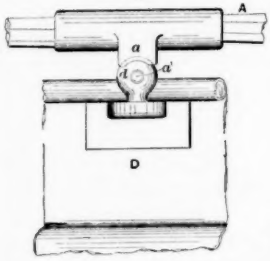
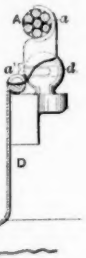


Fig. 4



of gravity of the needles and frame. One of these points rests on a flat support of sapphire or other suitable hard material, and the other point rests in a cylindrically-shaped support of similar hard material.

The needles are accurately balanced, so as to be horizontal when resting on the points before being magnetized, and

Fig. 5

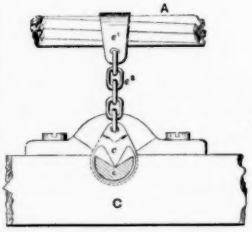


Fig. 6

they are then magnetized. The needles are brought to a level position again by a vertical magnet placed at equal distances from the four poles of the needles, and capable of being moved up and down. The position of the vertical magnet, according as it is higher or lower, gives a greater or less vertical force on the needles, the amounts of this force being determined by experiment for different positions of the vertical magnet.

This dipping-needles instrument is shown in Figs. 7 and 8; *i i* are the mag-

netic needles connected together by the framework, *j j*, and supported on the tops of the columns by two iridium points, *k k*.

When the instrument is used in the binnacle, the compass-bowl is taken out and the instrument is put in its place. The instrument is supported by cords from the elastic ring of the compass, which can be lengthened or shortened to adjust the instrument to the level and to the proper height, to bring the needles to the same position as the needles of the compass-card, when the bowl is in its place.

The binnacle, with the arrangement of correctors for correcting the semicircular, quadrantal and heeling errors, is shown in Figs. 9, 10 and 11. M M are the receptacles for the fore and aft magnets; M′ M′ are the receptacles for the thwartship magnets; and H is the Flinders bar. In Fig. 10 the dipping needles instrument is shown hanging in its place in the binnacle.

The binnacle contains mechanical appliances for realizing in practice the principles of correction discovered and published originally by Captain Flinders and Sir George Airey. The correctors for the several parts of the compass error * are as follows:—

To correct the "quadrantal error," a pair of unmagnetic iron globes (solid or hollow), fixed on each side of the binnacle.

To correct the "semicircular error," bar magnets, in symmetrically placed long horizontal† holes thwartships and fore-and-aft within the binnacle, and a Flinders bar (described below) attached to the binnacle outside on the fore or aft side.

To correct the "heeling error," three, two, or one bar magnets in a brass can hung by a chain, by which it can be moved up and down and secured in any position in a brass tube fixed in the center of the binnacle, under the compass-bowl.

The part of the heeling error which depends on magnetism transiently induced by the vertical components of the earth's magnetic force, is always partially and may be wholly corrected by the globes and the Flinders bar. The heeling error on the east and west courses is wholly corrected by the Flinders bar.

The corrector-magnets regularly pro-

Fig.7

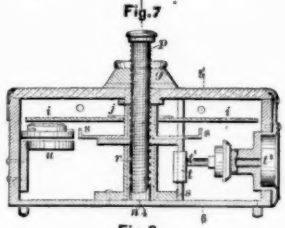
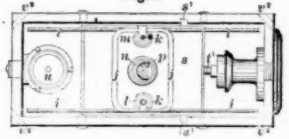


Fig.8



vided with the binnacle for the 10-inch compass are round bars of glass-hard steel, 9 inches long and .4 of an inch or .2 of an inch diameter. Each magnet is painted blue in one half of its length and red in the other half, according to a happy suggestion of Sir George Airy's; blue to mark the end possessing the same kind of magnetism as the earth's north polar regions, and red to mark the end possessing the same kind of magnetism as the earth's south polar regions.*

The fore-and-aft corrector-holes (shown at M M, Figs. 9 and 11) are in two verti-

* "Error of the compass" means the angle between the north and south line of its card and the correct magnetic north and south line. The error is said to be easterly when the north point of the card lies to the east of magnetic north, and westerly when it lies to the west of magnetic north. This use of the word error has official sanction in the Admiralty Manual, Section IV., in respect to the "heeling error." The word deviation is also used in other parts of the Admiralty Manual to signify the same as error, but the word error seems to express the meaning better, and has the advantage of being of two syllables instead of four. Some writers have defined error as the angle between the north and south line of the compass and the astronomical north and south line; but this definition conveys an altogether wrong idea of what the compass ought to do, and is not in any respect convenient. All confusion is avoided by adhering to the simple definition of error given above.

† The words "horizontal" and "vertical," with reference to fixtures in the ship, are used for brevity to denote positions which are horizontal and vertical when the ship is on even keel.

* The blue ends are properly called "true north poles," and the red "true south poles," but (because of the law that likes repel and unlikes attract, in magnetism) the true north pole points south and the true south pole north, if a bar magnet is hung horizontally by a thin thread, and therefore English instrument makers (still unmoved by Gilbert's protest 280 years ago) mark the true north pole S and the true south pole N. All ambiguity is removed in a particularly convenient manner by the Astronomer Royal's blue and red marking.

cal rows or scales, at equal distances of about 5 inches from the middle of the binnacle. The thwartship corrector-holes are in one vertical row (shown at M′ M′, Figs. 10 and 11), about the same distance forward or aft from the center of the binnacle. The holes in each vertical scale are spaced to give equal augmentations or diminutions of corrective force, when one of the corrector-magnets is shifted up or down from hole to hole in order. They are marked with numbers proportional to the corresponding corrective forces.

Fig. 9

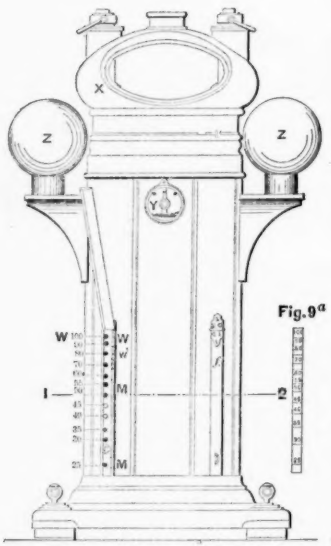
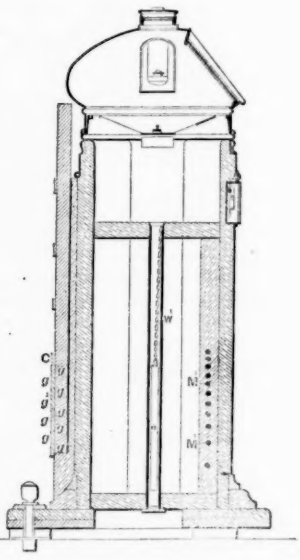


Fig. 9a

Fig. 10



One of the corrector-magnets, when held horizontally with its two ends equidistant from the center of the compass, exerts forces on the ends of the needles in lines parallel to its own length, and in opposite directions on the two ends of each needle. These forces, transmitted through the silk-bearing threads, pull the north point of the card towards the side on which the blue end of the corrector is held. Hence a pull * to port or to starboard is produced by a magnet in one of the thwartship corrector-holes, with blue end to port or to starboard; and a pull forward or aft, by a magnet in one of the fore-and-aft corrector-holes, with its blue end forward or aft. With magnets already in some of the corrector-holes, if a pull to port is wanted, it is had by raising one of the bars in the thwartship scale, if its blue end is to port, or lowering it or removing it or reversing it if its blue end is to starboard; and if a pull forward is wanted, it is had by raising a magnet in one of the fore-and-aft scales, if its blue end is forward, or lowering or removing or reversing it if its blue end is aft.

Westerly error,* when the ship's end is north, or easterly error, when the ship's head is south, is to be corrected by a pull to starboard.

Easterly error when the ship's head is north, or westerly error when the ship's head is south, is to be corrected by a pull to port.

Easterly error when the ship's head is east, or westerly error when the ships'

* A pull to port or to starboard, or a pull forward or a pull aft, is a short expression for a magnetic force pulling the north points of the compass-card to port, or to starboard, or forward, or aft.

* The error is called easterly when the north point of the compass-card is on the east side of the correct magnetic north and south line; westerly, when on the west side of this line.

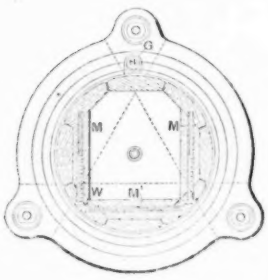
head is west, is to be corrected by a pull aft.

Westerly error when the ship's head is east, or easterly error when the ship's head is west, is to be corrected by a pull forward.

When the globes for correcting the quadrantal error have been once properly placed, no change of this adjustment is ever necessary for the same ship, and the same position of the compass in it, except in the case of some change in the ship's iron, or iron cargo, or ballast, sufficiently near the compass to sensibly alter the quadrantal error. But the magnetic correctors for the semicircular error and the heeling error must be adjusted from time to time, to keep the compass correct.

The Flinders bar supplied with the compass is a round bar of soft iron, 3 inches in diameter, and of whatever

Fig. II



length of from 6 inches to 24 inches is found to be proper for the actual position of the compass in any particular ship. To make up the proper length it is supplied in pieces of 12 inches, 6 inches, 3 inches, $1\frac{1}{2}$ inches, and two pieces of $\frac{3}{4}$ of an inch. In making up the proper length the longest piece should be uppermost and the others below it in order of their lengths. The weight of the bar is supported on a wooden column or bar, resting on a pedestal fixed to the binnacle near its foot, this wooden bar being cut to such a length, or so made up of pieces, as to give the proper height to the upper end of the iron bar. The compound column of iron and wood is kept in position and protected from rain and spray by a brass tube, with upper end closed, going down over it.

The main object of the Flinders bar is to counterbalance the component of the ship's horizontal force on the compass, which is due to magnetism induced by the vertical component of the terrestrial magnetic force. Hence, in all ordinary cases, the ship's iron being symmetrical on the two sides of the fore-and-aft midship vertical plane, and the compass being placed in this plane, the Flinders bar must be placed in it also, and therefore must be exactly in the middle of the front side, or of the after side, of the binnacle. The Flinders bar essentially corrects, wholly and permanently, the constituent of the heeling error, which has its maximum values on the east and west courses. A subordinate object of the Flinders bar, as supplied to my compass, is to partially correct the constituent of the heeling error, which has equal maximum values on the north and south courses, by partially counterbalancing the component force on the compass, perpendicular to the ship's deck, exerted by that part of the ship's magnetism which is induced by the vertical component of the earth's magnetic force. For this object also the proper position of the bar is up and down in the middle of the forward or after side of the binnacle; but for it the bar should be lowered a little below, or raised a little above, the position in which, without altering the length of the bar, it gives its maximum horizontal force on the compass. When it is not desired to make this contribution to the heeling correction by the Flinders bar, it should be placed with its top about 2 inches above the level of the needles of the compass-card.

To understand the action of the Flinders bar, suppose first the ship to be anywhere in the northern magnetic hemisphere.* The vertical force there is such

* The earth's surface is divided into two parts, called the northern and southern magnetic hemispheres, by a line called the magnetic equator, which is the line of no dip. This line is not a great circle like the true equator, but a sinuous line north of the true equator in all east longitude, and from 180° to 173° of west longitude: and south of the equator in all west longitude less than 173°. Its greatest distance on either side of the equator is where it cuts the coast of Brazil, in about 17° south latitude. Its greatest distance north of the equator is in the Indian Ocean, which it crosses from Africa, a little south of Cape Guardafui, to the south of India, very nearly along the 10° parallel of north latitude, and eastward across the mouth of the Bay of Bengal to the Malay Peninsula, still but little short of this degree of north latitude. A chart of lines of equal magnetic dip, such as the very convenient small scale one of the Admiralty Compass Manual, should be carefully studied.

as to pull the red end or pole of a magnetized needle downwards, and to repel the blue end upwards. It also has the effect of inducing magnetism in any mass of iron, so as to give it a transient magnetic quality marked with blue on the upper side or end, and red on the lower side or end. Thus, in the northern magnetic hemisphere the Flinders bar is transiently magnetized by the earth's vertical force in such a manner that it acts like a great bar-magnet, with its upper end blue and its lower end red. At the magnetic equator it loses its magnetism, and in the southern magnetic hemisphere it acquires magnetism in the opposite direction to that which it had in the northern hemisphere; so that now its upper end is red and its lower end blue. As the ship moves from one hemisphere across the magnetic equator to the other, the magnetism of the Flinders bar gradually* diminishes to zero, and then increases gradually in the contrary direction. The object to be attained in applying it to the binnacle is that, with this gradual change of its magnetism, it shall always, as exactly as possible, counterbalance the changing part of the force on the compass, due to the part of the ship's magnetization which changes with the gradual change of the vertical component of the terrestrial magnetic force. If this changing part of the ship's disturbing force on the compass is a pull aft in the northern magnetic hemisphere, and a pull forward in the southern magnetic hemisphere, the Flinders bar must be on the forward side of the binnacle. On the other hand, if the regularly changing part of the ship's force be a pull forward in the northern hemisphere, and aft in the southern hemisphere, the Flinders bar must be on the after side of the binnacle. The former is the most frequent case for the chief navigating standard compass and for the steering compass of modern mail steamers and merchant steamers generally, in which the steering and conning of the ship is done on a bridge forward of the engines, with considerably more than half of the ship behind it. It is also almost certain to be the case for an after-steering compass, a few feet in advance of the top of the iron stern-post and rudder-head, in an iron steamer or sailing ship. The second above-mentioned case is what will generally be found for a compass anywhere in the after half of the ship's length, to within two or three yards of the stern-post. Most frequently it is not possible to ascertain which of the two is the actual case until the ship has made a voyage through regions presenting considerable differences of vertical magnetic force. The best plan generally is, in first placing the binnacle on the deck, to turn it with the fittings of the Flinders bar forward or aft, according as it is found that the fore-and-aft correcting magnets have to be placed with red or blue poles forward or aft. It may be that the experience of a first voyage may show that the binnacle must be turned the other way to get the Flinders bar into its right position; but the chance of this being necessary is less if the binnacle is first placed according to the preceding rule, than if it is placed in the opposite direction without some knowledge to guide. If it has to be turned, the turning is done in a few minutes, for any binnacle made after January, 1880, as the binnacle has four feet, which are screwed by brass bolts to brass sockets fixed in the deck, and fitting for either side of the binnacle foremost.

In the first adjustment, or as long as there is special knowledge as to the proper proportion of correction to be made by the Flinders bar, it may be set to correct about half of the whole error on the E. and W. courses; the remainder must be accurately corrected by the fore-and-aft magnets.

Suppose now the first adjustment to have been made somewhere in the northern magnetic hemisphere, and suppose that as the ship goes to places of weaker vertical force the fore-and-aft correcting force required to make the compass correct on the east or west points, is found to be less than at the beginning of the voyage. It is clear that part of the correction made by the magnets ought to have been made by the Flinders bar. But nothing need be done except to diminish the fore-and-aft pull by the magnets, as long as the ship is going to places of weaker vertical force. If without touching or crossing the magnetic

* The change of polarity in vertical bars in the ship, which takes place in crossing the magnetic equator, has sometimes been falsely supposed to be abrupt, and mistakes in respect to compass courses have been made in consequence.

equator the ship returns again to places of stronger vertical force,* and if it is found that increased longitudinal pull is now required, this should be applied, not by the magnets, but by introducing a Flinders bar or by increasing the bar already in position.

Generally, for a ship making passages to and fro through regions of considerably different vertical force, whether she crosses the magnetic equator or not, the rule in respect of the fore-and-aft correction is as follows:

Correct the deviations found by observation on the east or west courses by the fore-and-aft magnets when the ship is going to places of weaker, and by the Flinders bar when she is going to places of stronger, vertical force, whether in the southern or northern hemisphere.

After a few voyages the proper proportion of correction by Flinders bar to correction by bar-magnets will be practically realized.

Commander CURTIS, R.N.: There are one or two points I should like to mention. A friend of mine, a navigating officer, once told me that he was on board one of our turret ships, and they went out to try her at Spithead. The compass had already been adjusted, but after firing they found the compasses were all wrong. I should like to ask if the concussion of the guns would alter the magnetism of the ship? Sir William Thomson tells us how sensitive the poker is to the slightest tap, and possibly the concussion of our heavy guns, especially being so near the turrets, might alter the magnetism of the ship. I have not been afloat in any ironclad, but I naturally take an interest in the profession, and should like to know how that is. The last time Sir William Thomson spoke with respect to the compass, I wanted to confirm what he said with respect to the blue and the red denoting the *proper* true north and south poles respectively. A merchant captain, in 1864, in command of one of these improved ships, with an iron deck and everything that could possibly be made of iron, on board the ship, was going from the Tyne to Coquimbo, bound round the Horn. The compasses were adjusted, and I presume that he in his happiness thought they would be all right to take them to Coquimbo and back again. But, unfortunately, when he got off the Horn, his chronometer went down, and he tacked always within eight points of the compass. He could not understand it: he put his helm up and ran into soundings, and he literally felt his way into Rio with his deep-sea lead, and he said if he had been at sea another week he would not have had a man left, they were so exhausted. I do not know what the Board of Trade Regulations are with respect to the examination of merchant captains and mates, but I think they should insist that upon the fly-leaf of every log-book, some simple instructions should be given for the correction of the compasses, and also stating for the benefit of the captains, if they do not know it, that when they have crossed the Line, the magnet acts just in the reverse way. One would hardly think that there are any merchant captains who do not know it, but this man certainly did not in 1864. The particular point I wish to ask is whether the concussion caused by firing the guns will alter the whole magnetic attraction of the ship?

Captain SAMUEL LONG, R.N.: I do not feel equal to following Sir William Thomson over the beautiful invention which he has just explained to us: but I must confess that I am very grateful to him for his goodness to the naval profession and the maritime profession at large. I am sure that many now cruizing about the ocean would agree with me in saying that. I should like to ask Sir William Thomson if he could give us any practical results by naval men or merchant captains as to the azimuth mirror for taking bearings, whether it has been found to be practically satisfactory and superior to the old Admiralty plan. Also whether the disturbance of the firing of guns on the compass has been

* "Vertical force" is a short expression for the vertical component of the earth's magnetic force. It is reckoned as positive when the direction of its action upon a red pole is downwards, as in the northern hemisphere; and negative when upwards, as in the southern hemisphere. At the magnetic equator it is zero. The amount of the vertical force at any place is calculated by multiplying the value of the horizontal force given by the chart of lines of equal horizontal force of the Admiralty Manual by the tangent of the dip as given by the chart of lines of equal magnetic dip. Thus, for example, the tangent of the dip for the south of England being 2.44, and the horizontal force there being called unity, the vertical force there is 2.44. The tangent of the dip at Aden is .09, and the horizontal force there is 1.95; hence the vertical force there is .1755, or about $\frac{1}{14}$ of the vertical force of the south of England.

satisfactorily met? The other day I was on board a new steel steamer—one of the newest steamers built—8,000 tons. I said to the chief officer: "What compass have you got?" He said, "We have got Sir William Thomson's." I said I thought it was very costly and difficult to manage. He said, "Oh, no, it is as simple as A B C; we never have any bother at all; it is always correct, and we never have the slightest trouble." I think that information from a practical man, who is constantly at sea, is worth a great deal more than anything I could say.

Lieutenant CHARLES CAMPBELL, R.N.: Without presuming to discuss the able paper to which we have listened, I may be allowed to say that I served two years on board the "Minotaur," which had Sir William Thomson's compass. We found it most valuable in alterations of course of eight points, and, in fact, during all manœuvres. The compass as she came up would settle exactly on the point. The improvements of which we have heard to-night seem to me of the greatest value, and I think Sir William Thomson has given to the Navy a compass that will stand when the guns are in action, and be true to the Pole, he will have done as much for the Navy as if he had discovered the Pole itself.

Staff Commander CREAK, R.N.: Being particularly interested in the compass question on board ship, I propose to make a few remarks on the subject before us. Whilst explaining the construction of his instrument for correcting the "heeling error" on board ship, Sir William Thomson has laid much stress on the importance of knowing or being able to estimate, the value of what is known as λ (lambda), in the notation of the Admiralty Manual. He has given us various estimates of its value from. 6 to .95, according to class of ship. Some of those present to night may not be aware that the Admiralty system more fully recognizes the value of λ by not merely trusting to its being estimated, but by ensuring its being ascertained by actual experiment for every class of vessel in the Navy. The value of the vertical force, or μ (mu) of the Admiralty Manual is also ascertained in every ship. Sir William Thomson also referred in his remarks to the vertical force of ships. His remarks are perfectly clear on the subject, except in one respect, namely, that the vertical force is generally downwards. Perhaps Sir William Thomson has not the same advantage that I have in knowing the magnetic character of every ship of the Navy. The vertical force in her Majesty's ships is more generally upwards, from the fact, that the ships built in our own dockyards are, in most part, built with their heads in a southerly direction. The ship's stern is, therefore, magnetized with red magnetism; therefore the vertical force acts upwards, and that, meeting the downward pull caused by the soft iron of the ship, is in great measure counteracted. I am now speaking of ships such as the larger ironclads (not turret ships), the "Northampton," and similar vessels. Sir William Thomson kindly referred to a paper of mine, that was read before the Royal Society on the question of the effects of the iron masts in the "Undaunted" on her compasses. Although in that case the effects were very important, I do not think it was the cause of the upward force of the "Northampton," because she was built at Elder's yard, on the Clyde, with her head in a southerly direction, and according to the usual effect of the earth upon a ship in such a position, the after part of a ship where the compass is placed, would receive red magnetism, and the vertical force act upwards; but had her compasses been brought near her masts, the upward vertical force would have been very great. The effect of the masts was so great in the case of the "Undaunted," that we had to correct the binnacle compasses by vertical magnets, a thing which has never been done before in a wooden frigate. Sir William Thomson spoke of the large changes of ships going to the Cape, and he very truly said, the Flinders bar was a good thing in correcting that error. He has referred to ships having errors of 30° or 40°. I know of an instance communicated from the Board of Trade, in which there was an error of 40° in a vessel's compass there, which had been correct in Sunderland; but then one must consider, the compass was not placed according to knowledge. It was placed near the stern, and there, of course, it was too near a vertical enormous Flinders bar—the stern-post, a bar affected by the vibration of the ship.

The result was, she changed as much as 30° to 40°. But in our ships, where the compasses, I may say, are placed according to knowledge, the changes are remarkably small. Take the "Volage," for instance. The "Volage." in going from England to the Cape, scarcely altered at all. The change from the transverse force was only 2°. The part that would be expected to change most was from the fore and aft magnetic force, but that only changed $1\frac{3}{4}$°. That, I conclude, resulted from the judicious position in which the compass was placed; and, therefore, in that case, the Flinders bar would have been of no use. But I can see the use of it when people who build ships will insist on putting their compasses in any place, just as it happens to suit their convenience. There are a few of our ships which have not been so satisfactory lately as the "Volage," the ships of the "Gem" class. The deviations in these ships in going from England to the Cape, have altered as much as 8° to 9°, and, perhaps, there a Flinders bar might have been useful; but not to the same extent that Sir William Thomson has found in merchant ships. Another subject which has been referred to, is the question of firing guns. That has been thoroughly gone into, and the result on iron of firing guns is similar to what you have just seen with the poker. If you put the compass on a thin iron structure, as it is necessary to do in our turret ships, firing guns continually alters the magnetism of that thin iron structure, producing new errors in the compass so placed, and nothing can help it—no Flinders bar or any other magnetic corrector can prevent it, and I should be very glad if anyone will find some system of meeting the difficulty. No man of science has ever brought forward any proposal for preventing the magnetism of iron being altered by concussion from whatever cause. The ships that have altered most have been those of the "Thunderer" class, and we expect it. The captains of these ships are warned accordingly, and especially so. The navigating officer is the officer who has most time to attend to these things, and whose especial duty it is to look after the compass—that compass may be made perfectly correct, and yet after firing, or perhaps, if the ship has been lying in any direction for a certain length of time it is quite enough to temporarily alter the magnetism of the ship. I do not wish to detract in any way from the merits of the compass on the "Minotaur's" poop, which has been mentioned to-night, as it does its work efficiently; but there is nothing whatever to prevent a compass of the Admiralty pattern being put on the poop of the "Minotaur," and being made equally correct to that of Sir William Thomson. In saying this, I wish to point out that we are not behindhand in the Service, but have every means at our disposal for making a correct compass for tactical or other purposes.

Sir WILLIAM THOMSON: Captain Curtis asked a question which has been very clearly answered by Captain Creak. I may add that the "Glatton" showed that effect very remarkably, on the occasion of the particular service squadron under Sir Cooper Key, going from Portland to Portsmouth for the Naval Review in 1878. While steaming out of Portland, my compass on board the "Glatton" was found to be quite correct on all points. Then, by order of the Admiral, the "Glatton" steamed out of position in order to have some trials of the compass under gun-fire. The question as to the steadiness of the compass was satisfactorily answered. The compass remained perfectly steady, and was quite serviceable during the firing of the heavy guns. The question of the effect of the concussion produced by the firing upon the magnetism of the ship was also gone into, and I found an easterly error of 5° when the ship turned to north, immediately after the gun-firing on an easterly course. After a little steaming on various courses, at ordinary speeds, this error became much diminished, if not annulled, in the course of half an hour.

Captain CREAK: The compass, when it has been altered by gun-firing, as a rule takes some days to relapse into its former position, but it does relapse gradually.

Sir WILLIAM THOMSON: It is not to be supposed that any *automatic* appliance can be placed on board ship which will cause the compass to point always correctly. My object has been to cause the compass to point correctly by means of adjustment and readjustment performed methodically, by a safe and easy process, when found necessary. The navigator must always be on the watch, to examine the compass and allow for any error he

finds. Small changes that may be transitory may be left to themselves, but changes which show themselves, week after week persistently, should be corrected by a slight readjustment of the correctors. Captain Long asked if the azimuth instrument has been found practically satisfactory? I may answer that question by saying, referring to a very satisfactory report communicated to me some time ago by the British India Company, having been received by them from Captain Smith, of their steamer "Malwa," which has had a compass of mine on board. The previous captain had left no record of the errors of any of the compasses, except on the courses actually steered, and Captain Smith joined the ship at a port (Busreh) at the head of the Persian Gulf. With a compass that he had never seen before he naturally felt uneasy, because he was going on different courses to those for which he found the compass errors recorded; and he had absolutely no guidance as to what errors might be expected on the course he had to steer, but he had read my book of "Compass Instructions" during the few days he was in port. Happily, after getting out of port he had clear weather, which allowed him to take bearings of the Pole-star with the azimuth mirror. One important quality of the azimuth mirror is the exceeding ease with which it can be used at night, for stars, even in a heavy sea, with considerable rolling and yawing of the ship. Captain Smith corrected the compass by the magnets, according to the printed instructions, in about an hour. He then put the ship a second time round, and verified that there was no error, and after that he went on his course with full confidence.* He reports that ever since he has had no difficulty in keeping the compass perfectly adjusted at sea. The azimuth mirror has been very extensively used in the merchant service. Captain Lecky, now of the British Shipowners' Company, has taken a great many star azimuths, and reports that he is very much pleased with the results. Captain Long also asked if the performance of the compass was satisfactory during firing? It being perfectly satisfactory in the "Northampton" and in the "Glatton." I have seen it, also, in firing salute-guns in the "Euryalus," and the result has been perfectly satisfactory.

Staff-Commander CREAK: May I be allowed, Sir, to add a little to the remarks I have already made, by saying that in any remarks I have made with regard to Sir William Thomson's compass, I hope that the meeting will consider I am not casting any reflection upon it. That compass is now on trial in the "Northampton" by order of the Admiralty, and I am sure it will receive every possible attention and fair play. We shall be glad to hear that it has answered its purpose in every possible way.

Captain CURTIS: I think we understand Sir William Thomson to say that this compass will resist firing. That is just what we are told the Admiralty want—a compass which will not be out of order during firing or after.

Sir WILLIAM THOMSON: My compass gives perfectly steady indications during firing; but whatever change takes place in the ship's magnetism by firing, is shown in my compass as in every other compass. Other compasses, however, may be so severely shaken by the concussion of firing, as to break the point or cap; and it is not safe to leave them in position. One great object I have aimed at has been to provide a compass which need not be lifted off the bearing point during firing, and which can be used for navigation of the ship during gun practice or in action.

The CHAIRMAN: There is one remark made by Sir William Thomson which I think all those who have to navigate ships should lay to heart, and that is, that notwithstanding all his ingenious arrangements and improvements of the compass, he dwells upon constant observation, constant care, and constant watchfulness, to see that the errors are corrected. I have heard that it is not, perhaps, so much attended to as it should be in the merchant service. The officers of that service too often have their compasses corrected by experts at home, and pay very little more attention to the matter. It is manifest, that whatever may be the ingenuity displayed in correcting compasses, nothing can supersede careful observations. I think we are all deeply indebted to Sir William Thomson, a man of high scientific attainments, for coming here this evening, and explaining this very interesting in-

* "I had done in one short hour on a dark night with this new compass what would have been simply an impossibility under the same circumstances to have done with an ordinary compass."—Extract from report of Captain H. B. Smith, dated Calicut, Feb. 15th, 1880, to the British Indian Steam Navigation Company.

strument. We have heard a most instructive paper, and hope, as Captain Creak has expressed it, that the compass now on trial may prove as great a success as Sir William Thomson wishes it to be. With your approval, I will return our grateful thanks to Sir William Thomson for his very valuable paper.

THE UNITED STATES SIGNAL SERVICE.

Abstracts from the Report of the Chief Signal Officer, GEN. M. B. HAZEN, to the Secretary of War.

THE Signal Service has had its growth in the generous support of the American people, and year by year an increased confidence has been shown in the usefulness of its work; a confidence that has steadily augmented with the development of the Service. The Weather Service of the United States has been without a rival in the practical advantages derived from its labors, but the day has now come when it should take its stand among the foremost, in the scientific study and investigation of the higher branches of theoretical meteorology, and it is upon such investigations intelligently pursued that the hope for greater benefits must mainly rest. I have endeavored to bring this Service into active sympathy and co-operation with the ablest scientific intellects of the country. In this direction, and in response to my request, the National Academy of Sciences has appointed an advisory committee of consulting specialists with which I may confer as occasion demands. I take pleasure in acknowledging this courtesy as showing the establishment of more intimate relations between the scientific interests of the United States and the Signal Service.

This year has been distinguished by additional progress and by decided improvement which I will briefly recite: The establishment, under your sanction, of a permanent school of instruction at Fort Myer, Va.; the raising of the standard of the personnel of the Signal Corps; the systemization of the duties of the Signal Service; the preparation of new instructions for observers of the Service; the preparation of new and improved forms for the recording and preservation of meteorological data; the preparation of special bulletins for the press, containing weather information of public interest; the forecasts of weather, of hot or cold waves for periods exceeding twenty-four hours; the forecasts of "northers" for the interior plateau; the adoption of a new storm signal (the Cautionary Northwest) for the interior lakes; the arrangement for increase of river service, and wider publication of warnings of floods or ice gorges; the changes and improvements in the publication of the "International Bulletin," and the "Monthly Weather Review," with their accompanying charts; the increased information added to the "Farmers' and to the Railway Bulletins;" the organization of a service for the special benefit of the cotton interests of the South; the extension of the special frost warning to the fruit interests of the country; the investigations into thermometric standards, and into barometric standards; the preparation of new hygrometric tables containing correction for altitude; the revised determinations of the altitudes of Signal Service stations; the computation of monthly constants for the reduction of observed barometric pressures to sea level; the arrangements for original investigation in atmospheric electricity, in anemometry and in actinometry, and, in the last subject, especially with reference to the importance of solar radiation in agriculture and the absorption of the sun's heat by the atmosphere; the co-operation in an expedition to the summit of Mount Whitney, California, for the determination of problems in solar physics; in metrology, the preparation of conversion tables for the English and metric systems; the co-operation in the dropping of time balls at Signal Service stations; the publication in quarto form of special professional papers; the offering of prizes for essays of great merit on meteorological subjects; the organization of State weather services; the new

investigation of danger lines on Western rivers; the organization and equipment of two expeditions for meteorological observation and research in the Artic regions of America, one to be stationed at Lady Franklin Bay, the other at Point Barrow, Alaska, both co-operating in this work with a system of stations established in the Polar region by international conference; the establishment of a system of stations of observation in Alaska; the arrangements for organizing a Pacific Coast Weather Service; the display at the Paris Electrical Exposition; the experiments for improving newspaper weather charts; the increase since June 1st of telegraphic weather service, exceeding in value $34,000 per annum, without additional expense to the United States, and the extension and construction of military telegraph lines.

All these subjects are treated in full in the body of this report.

There has been continued at Fort Myer, Va., the established course of theoretical and practical instruction in military signaling, in international signaling, in the use of different ciphers, in military surveying and the use of surveying instrumeuts with topographical mapping, in electricity and the electric telegraph, in telegraph practice, in the construction of telegraph lines, on land or under the sea, and in meteorology.

Experiments in signaling and telegraphy are made at Fort Myer under proper supervision. It is endeavored to keep up in all improvements with the progress made by scientific ingenuity in the special duties of the service, in the use of improved war material, and in the different modes of rapid communication now necessary and expected to be used in war. With each ensuing year the duties of corps analogous in their service to the Signal Corps, become more prominent, and hardly a month passes without some suggested improvement in telegraphic or signal apparatus, or in the methods of using them. Such are here tested as may have received the notice of this office, or to which attention is directed by higher authority. It is by following plans determined by tests made at this office and at Fort Myer that the proper construction of the iron lines now so successfully used on the sea coast and for the connection of posts, settlements, and stations on exposed frontiers and in the uninhabited interior has been secured.

A series of experiments has been made with sun flashes, with a view of improving upon the forms of heliograph to be adopted for the general uses of the Army, and it is believed that the improved heliograph selected combines great simplicity with efficiency, and possesses many practical advantages, so far as known, over similar instruments in other services.

The importance of the field duties of the Signal Service, and of the modes of communication such services make possible, are now recognized throughout the world. The modes of instruction in field or out-door signaling, now nearly similar in the Army and Navy of the United States, ought to be made absolutely so, and a course established so complete that any force of either arm will be surely competent at any time to put itself in signal communication with any other force, either of its own, or of the other arm, within signal distance. It is not necessary now to represent at length to any who are familiar with the operations of recent warfare the propriety and the need that an armed force of any army should be able to telegraph to, or to communicate by signals with, any other force of the same nationality, or obeying the same general command.

The habitual practice of the more simple duties of field signaling and telegraphy ought to become a part of the regular exercises adopted for the militia forces of the different States. To a small extent this practice has been already entered upon in some of the States.

The enlisted men of the Signal Corps are engaged on duty as constantly in time of peace as in the presence of actual war. The uses of the post at Fort Myer, for the discipline and instruction of the officers and enlisted men of the corps, do not cease while they remain in the service. The force, made useful in time of peace by employment through which it returns to the United States more than the cost of the service, is kept in readiness for any emergency of armed duty by regular drills, in which the officers and men stationed at this office, and those whose changes of station

bring them even temporarily within reach of Fort Myer, are occasionally joined.

The advantages of distributing in the different cities of the United States a force of men, with such training, habituated to acting promptly and in concert, capable of reporting by telegraph and in cipher, as a duty, upon matters of military interest to which their attention may be directed, aside from the routine duties of their station, have been sufficiently manifested. The self-possession of the non-commissioned officers in charge of stations, their prompt, concise, and reliable reports, rapidly collected over great extent of territory, for the information of superior authorities, in emergencies which have occurred, have received the warm commendation of officers high in rank. To rapidly make reports of this character and to collect them over the telegraph wires, by ærial signals, or by other methods of communication, is the especial duty required of the Signal Corps in time of war, and its services have been made available for the collection of trustworthy information during great national excitement in time of peace.

The legislation of the act approved June 16, 1880, increasing the enlisted force of the Signal Corps by fifty additional men, has been and will be productive of good results. This and previous legislation has fixed the service on an honorable footing, and opened a reputable career to the best class of young American citizens. The applications for enlistment are numerous. The severe examinations are successfully undergone. The clause providing "that two sergeants may in each year be appointed to be second lieutenants," gives that stimulus of permanent service and promised reward so long and earnestly sought for.

The work aggregating at the office of the Chief Signal Officer has become each year more extensive. A field of operations actually co-extensive with the northern hemisphere is now within its scope.

The details are many and complicated, each requiring to be elaborated with the many checks necessary for accuracy, and each limited for its discharge to fixed and brief periods of time.

The organization of the service, improved by experience, has permitted each branch of duty to be carried on with regularity. The force on duty at this office, small in view of the onerous and extensive duties devolved upon it, has been at times, and necessarily, overworked,

In rendering these duties it ought to be borne in mind that they are continued day and night without cessation for holidays or days of rest. There is no single day of the year in which the work is suspended. It must of necessity and for this reason be performed by details of men who relieve each other at fixed times. The total force employed at this office numbers one hundred and ten en listed men,

In estimating the numbers required to be present for duty, it is difficult to make a comparison between an establishment thus conducted and others in which the work is limited to certain hours of daylight only. This office is the center to which the daily and nightly, weekly and monthly contributions of all other offices or stations of the Signal Service, scattered throughout the United States, tend to be daily condensed, and finely elaborated and made of practical value. There are concentrated, also, the reports from the five hundred and eighty-two places at which voluntary reports of daily observations are now made on this continent, and from three hundred and six locations in foreign countries from which reports of daily simultaneous observations are had. From the great mass of data thus collected, and which enhances each year in value, are continuosly elaborated the results which appear in the different issues of the office, whether in the form of forecasts telegraphed to the press throughout the country; of charts or bulletins distributed hence; of generalizations announced as apparent; of cautionary signal orders, or the weekly and monthly publications. No single report of any observation received at the office fails to receive attention or study.

The total number of daily reports, of all kinds, now received and filed at this office, is as follows: Number of daily service telegraphic reports, 247; number of international daily simultaneous reports, 521; number of reports from voluntary observers, 334; number of reports received from the Medical Corps of the Army, 83; number of reports re-

ceived from United States Naval Observers, 36; making a total of 1,221 reports received regulary for discussion.

It is from this office that the management and supervision of telegraphic lines, erected and now worked by the United States, upon the Indian frontier and in the States and Territories of the interior is controlled. The wires of the coast lines have here their terminal connection, and here concentrates the labor of the different coast stations. Upon this office devolves, and with each year to an increasing extent, the duty of transmission of many and important messages from superior authorities to and from distant posts and parts of the United States, for the safe delivery and proper guarding of which, by cipher, if need be, this office is responsible. The rooms of the telegraphic department are never closed or left without an operator. The brief narration possible in a report of this character can convey but little idea of the various and incessant labors incident to such an establishment.

The *Scientific and Study Division*, which was established January 27, 1881, for the purpose of scientific research and investigation into the laws of meteorology. Connected with this division are consulting specialists, who are employed as occasion may require. To this division also are referred all questions relating to standard measurements, altitudes of signal stations, and the preparation of tables for the reduction and conversion of meteorological observations.

ECONOMY IN ADMINISTRATION.

I have undertaken the thorough systematizing of the work in the Property and Disbursing Division of this office, and to secure the more economical expenditure of, and more ample checks upon, the disbursements of public money. Much has been already accomplished, and it is believed that large savings can yet be made in the efficient administration of the bureau, by still further substituting the mail for the telegraph, by a more careful condensation of sentences used in telegraphing; by revision and substitution of arbitrary cipher codes; and by the proper omission of certain telegraphic reports. By a complete revision of all the telegraphic circuits used by the bureau, without an actual reduction of the pay roll of the telegraph company, we have, without any additional cost, secured service in providing information for all the large cities that is essentially necessary to them, and was constantly called for, and that would otherwise have cost thirty-four thousand dollars. This is practically a saving of that amount. I have since endeavored also, by making the assignment of observers at stations more permanent, to reduce by a large sum the cost of transportation of these men from place to place. On account of the very rapid enlargement of the service of this bureau, the amount thus saved to the United States will not appear as large in my annual estimates as it otherwise would, but I will still endeavor to reduce them by seventy-five thousand dollars for the two items, the maintenance of the weather bureau and telegraph lines, below the cost of the past current year, and I have reasonable hopes at a later period to make still larger savings.

STATION DIVISION.

Signal-Service Stations.—The total number of stations of observation in June 30, 1881, within the territory of the United States and maintained for the Signal Service, was two hundred and ninety-six, including those upon the telegraph lines in charge of this office, and the special river and sunset stations, from which reports are regularly received. Reports are also received from seventeen additional stations established by the authorities of the Dominion of Canada, also from one at St. John's, N. F., and one at York Factory, B. A. Telegraphic reports have been regularly received throughout the year from one and mail reports from two stations located in the West India Islands, and during a portion of the year telegraphic reports from five and mail reports from three others. The number of stations from which telegraphic reports are received at this office tri-daily is one hundred and forty-two, the number from which one telegraphic observation only is received daily is twenty-eight, and from which two telegraphic reports are received daily is one; making the total number of separate points from which telegraphic reports are received daily, one hundred and seventy-one.

The sums expended for the service secure for the United States not only the reports from the officially-established stations, but incidentally those had from the additional stations, to which reference is made elsewhere.

The territory of the United States is not yet covered with stations as it ought to be, and valuable opportunities for study, which must be made good hereafter, and at an increased expense, are lost. The field of labor has increased greatly each year, as it has been learned how labor may be turned to the best benefit of different classes of citizens. The number of stations established in Alaska has been increased in response to numerous demands. The amount estimated as necessary to be appropriated for this service for the ensuing year, the sum of three hundred and fifty thousand dollars, can be wisely expended. The whole working force of the corps, five hundred men, will be constantly employed, and, in some instances, overworked. The services of citizens, in addition, will be needed as in preceding years.

The reports of observations had in ceaseless succession from the stations already established, while daily and primarily employed in the studies needed for the daily issuing of forecasts and the display of cautionary signals, form also the basis for future work, to be of equal value with that made possible by the first use of them, and to constitute a record, to increase in worth hereafter with every year for which it is continued.

The duties of the enlisted men at each station are as follows:

At stations forwarding telegraphic reports they are required to take, put in cipher, and furnish, to be telegraphed tridaily on each day, at different fixed times, the results of observations made at those times, and embracing, in each case, the readings of the barometer, the thermometer, the wind velocity and direction, the rain gauge, the dew point, the character, quality and movement of upper and lower clouds, and the condition of the weather. These observations are taken at such hours, at the different stations, as to provide the three simultaneous observations taken daily at three fixed moments of physical time throughout the whole extent of the territory of the United States.

On November 18, 1879, the times of taking the morning telegraphic observations were changed to a time thirty-five (35) minutes earlier, viz.: from 7 hours 35 minutes A. M. to 7 hours A. M., Washington mean time. On the same date the times of taking the afternoon telegraphic observations were changed, so as to be taken one (1) hour and thirty-five minutes earlier, viz.: from 4 hours 35 minutes P. M. to 3 hours P. M., Washington mean time.

These changes were made in order that the intervals between the observations should be uniform, viz.: eight (8) hours, it having been impracticable to change the time of taking the 11 hours P. M., Washington mean time, observations.

Observations, however, continued to be taken at 7 hours 35 minutes A. M., Washington mean time, at all the Signal Service stations, for the bulletin of International Meteorological Observations, until the change of time was made by foreign observers on January 1, 1881.

In addition to the three telegraphic reports, two, taken at hours simultaneous, viz.: 11 A. M. and 7 P. M., Washington mean time, are made and recorded at each station.

A sixth observation is required to be taken at the exact hour of sunset at each station. This observation, which calls for a careful study of the western sky, and such other local signs as may presage fair or foul weather for the ensuing twenty-four hours, is reported with the midnight observation.

At the stations at which cautionary signals are displayed, an observer must be constantly on duty to receive the order and to show the signal, which may be ordered at any moment. At stations from which river reports are furnished, an observation and record of the depth of the water is made and reported at a fixed hour on each day. In cases of threatening storms or dangerous freshets, any station may be called upon to make hourly reports. In cases of violent thunder storms, reports are sometimes required to be made hourly during its continuance.

FARMERS' BULLETINS.

The plan of exhibiting as widely as possible in the agricultural districts throughout the United States, the results

of the daily office studies, in the form of printed forecasts for the benefit of the agricultural populations, frequently described in former reports, has been continued in operation. The effort to cover so wide an extent of territory has made the labor great. This publication contains a synopsis of the weather conditions which have prevailed over the United States for the preceding twenty-four hours, as well as selected "Indications" of interest to the respective districts where these bulletins are circulated. The continuance of the work has been warranted by the favor with which it has been received. It has been considered due to the farming populations that they should have an opportunity to profit by whatever information could be given them. With the active co-operation of the Post Office Department, with which there is an arrangement for this purpose, six thousand six hundred and seventy-two Farmers' Bulletins, on which have appeared the reports of this office. have been distributed and displayed in frames daily at as many different post-offices.

The information given on these bulletins has a value in addition to the synopses and forecasts. The general law accompanying weather changes in the United States and facts relating. to the climatology of the different sections are condensed into brief notes, which are published with the telegraphed reports. For instance, each bulletin announces for the geographical district in which it is displayed, what winds in each month have been found most likely and what least likely to be followed by rain at the stations within each district. Diagrams, showing the circulation of winds out of a high and also into a low barometer, also appear upon these bulletins. These simple foot-notes have their effect in increasing the gains and reducing the losses of harvesting. These bulletins will improve for the uses for which they are intended, as the experience of the office permits the information they exhibit to be supplemented with further data and other rules. With each year the popular knowledge of the uses of the bulletin and the increased interest in and study of meteorology, render the farming communities better able to judge of its correctness and to benefit by its contents. It is contemplated, as the work of the office progresses, to add to the bulletin such brief instructions as may be practicable in regard to its uses in connection with such instruments as may be attainable for local observations. Reference has been made in preceding reports to the economy of this work. Careful estimates have shown that if the cost for each station at which the bulletin is displayed was computed to be twenty-seven cents per day, the total sum would meet all the expenses caused by the Signal Service. A little saving on one crop of grain made on any one day in the vicinity of each station, supposing nothing to be saved on any other day of the year at or near that station, would more than counterbalance the expenditure.

REPORTS FOR THE BENEFIT OF THE COTTON INTERESTS.

In compliance with the promise contained in the last Annual Report, to largely increase the usefulness of this Service to the great cotton interests of the South, a correspondence was opened with the representatives of the Cotton Exchanges to take into consideration the advisability of establishing a large number of auxiliary stations in the cotton belt. The plan contemplated was that these auxiliary stations should be situated on railroads, or at points having general telegraphic communication. The railroads traversing the cotton belt were requested to co-operate by requiring their agents, at selected stations, to take, as a part of their railroad duty, rain-fall and temperature observations, which were to be telegraphed free, as railroad business, daily, to selected centers, for distribution at the expense of the Signal Service, to the Cotton Exchanges in all important cities in the cotton region. To railroads undertaking co-operation, the Signal Service promised to furnish rain-gauges, maximum and minimum thermometers, instrument shelters, and the necessary stationery. The proposed system would ensure to all exchanges concerned complete and accurate information, each morning. as to the meteorological conditions existing in the entire cotton-growing belt. The railroads owning their own telegraph lines responded very generously to the appeal made to them. On other roads, where the lines were owned by the

Western Union Telegraph Company, the question was raised if, under the conditions of the contract between the railroads and telegraph company, weather reports could be transmitted free to the centers of distribution. Upon representation to the Western Union Telegraph Company, it, with great liberalty, consented to the free use of its wires for this special purpose. All the earlier difficulties attending the organization of this Service were speedily and favorably adjusted. Two hundred and forty-eight auxiliary stations were promised, which opened to the United States a very favorable opportunity for obtaining meteorological data, at a very slight expense, from a region whose agricultural interests depend, to an unusual extent, on climatic conditions, not yet as well understood as they should be. Unfortunately Congress did not appropriate the amount which had been carefully estimated as necessary to meet the expense of the increased work proposed for the signal Service, and I was very unwillingly compelled to reduce the number of stations to be established to one hundred, selected from the two hundred and forty-eight stations promised, which are so situated as to best cover the cotton belt. I very earnestly hope that Congress will this year provide the funds necessary for a great extension of this special feature of the Signal Service, which promises, with a very small expenditure, such great practical advantages to the staple interests of the South.

Special Bulletin.—This year, for the first time, the Chief Signal Officer has caused to be prepared and issued, twice daily, special bulletins for the press, containing meteorological information, of popular interest, to a greater extent than can appear, for want of space, in the official synopses and indications. They treat especially of high winds, severe storms, tornadoes, heavy rain-falls, floods, extreme temperatures, sudden and great changes in temperature, frosts, temperatures specially reported from health resorts, during the season when frequented, and, when the conditions sufficiently warrant, fair or rainy weather, as the case may be, predicted for two days in advance. There are also forecasted the movements of the so-called "warm waves" and "cold waves."

In addition, the Chief Signal Officer causes to be regularly made, daily, each morning, by all officers who are liable for detail in the Indication Division, forecasts or deductions of the weather conditions for the day succeeding that on which the forecasts are made. If the result of these studies is sufficiently successful, indications will in time, be issued for all districts for periods of more than one day.

The confidence of the people, as a whole, has not been sensibly lessened at any time, by the errors and omissions which sometimes occur, owing to the fact that in the present condition of science, and with a system of observation still too limited, premonitions having for their scope a territory so great as that of the whole United States, and embracing the coasts of two oceans, cannot always be correct for every part of a district.

RIVER SERVICE.

The river reports, giving the average depth of water and notices of the dangerous rises in the different great rivers of the interior, for the benefit of the river commerce and the populations in the river valleys, have been regularly made, telegraphed, bulletined in frames, and also published by the press at the different river ports and cities.

The manner in which these reports are prepared and used, and the mode by which a "danger line" has been determined with water below which there is considered to be no danger, while every rise above it is dangerous, have been sufficiently explained in preceding reports.

The information published in reference to this danger line, in connection with the daily reports of this office, has, on the occurrence of river floods, enabled those interested to judge of the probable limits of the rises of water to be expected at the different places on the river-banks, and of the dangers to be anticipated. This knowledge has made possible necessary precautions for safety.

The data received at this office from stations making river reports permit a foreknowledge of changes likeiy to happen, and make it possible to give useful warnings of coming floods, ice-gorges, or of sudden and great rises of the river water-levels. The daily reports are also useful at times of low water, the inform-

ation they then give permitting river shipping to be moved with intelligent foreknowledge of the probable depths of water to be found in the river channels at different points upon the river's course. These reports, having an official character, are especially useful to those for whom they are intended.

In instances which have attracted the attention of this office, the notices of the probable heights anticipated or passing floods would attain have been followed by preparations made to guard against danger. A brief examination of the charts of changes of the river levels, accompanying this and preceding reports, shows that the river rises to occur at the different localities, and their extent can be judged of frequently by the conditions existing at points sometimes far distant. Accumulating data render studies of this kind valuable. In connection with these studies the examination of the daily weather-charts, showing places at which precipitation has occurred or is likely to occur, and the amount of such precipitation, had with the study of the charts of the river basins, which enable it to be determined what rivers will be affected by precipitation, are to be found of value in furnishing correct prognostications.

The opinion is again expressed that with proper study of the river floods, and with stations properly placed, reporting at times of especial danger, it can be made almost impossible for a flood to follow a river course without notice being given, in advance of its coming, to the localities threatened.

FROST WARNINGS.

In November, 1879, for the first time, special frost indications were ordered to be forecasted and telegraphed from this office to New Orleans, for the benefit of the sugar interests of Louisiana. Special attention has since been given to the early forecasting of anticipated frosts for the sugar regions from the 1st of October to the 1st of February of each year. The warnings are given as early as they can be with reasonable safety; if possible, three days in advance. This information is telegraphed to the observer at New Orleans, and immediately upon the receipt of the message announcing anticipated frost, it is furnished to the press, bulletined at the Cotton Exchange, sent over the city by telephone, telegraphed to interested towns and parishes, and, where no other facilities are available, the information is sent by mail. The success of the special forecasts for the autumn of 1880 is sufficiently shown by the following resolution passed by the Chamber of Commerce of the city of New Orleans:

"*Resolved*—That the action of the Signal Service in giving the recent frost warnings, which enabled our sugar planters to guard against injury to their crops, deserve the approval of the planters and merchant factors of Louisiana, as having added to the confidence of investment and to the value of the culture of a staple important to American independence of foreign supply."

The Chief Signal Officer, by reason of the success of the frost forecasts for the benefit of the sugar interests of Louisiana, has been encouraged to undertake this year, for the first time, similar warnings for the benefit of the Orange interests at Florida, and also of the fruit interests of other points exposed to danger from frosts.

The co-operation of the Navy of the United States in the taking of observations simultaneously and in accordance with the system adopted at this office, wherever naval vessels of the United States may be, as established by the general order of the Secretary of the Navy, dated December 25, 1876, has largely increased the data of this class. This co-operation has been skillfully rendered by the Navay Department and the United States Navy, through the commanders and officers of vessels and the Chief of the Bureau of Navigation.

The people of the United States are thus the first nation whose Army and Navy co-operate, as all armies and navies should, under official orders, in the taking of simultaneous observations wherever the forces may be. This co-operation has now existed for nearly five years.

A copy of the daily International Bulletin exhibits the character of the international reports and that of the information had from each station. The charts accompanying these bulletins show, as nearly as practicable, the locations of the stations and foreshadow the studies which the reports taken from them will make practicable.

The average number of daily simultaneous observations now made in foreign

countries is three hundred and six. The total number of stations on land, and on vessels at sea from which reports are entered in the bulletin regularly is five hundred and twenty one. The co-operation of the different nations, secured by this plan of exchange, has rendered the additional cost to the United States of this grand system of reports but little more than that of the cost of the preparation, paper, and binding of the International Bulletins and the accompanying charts, at a cost which would be incurred in great part for the proper presentation of the records themselves, even if these bulletins were not distributed.

The issue of the daily International Weather Map was commenced July 1, 1878. Each daily chart is based upon the data appearing upon the International Bulletin of same date. The charting extends around the world and embraces for its area the whole northern hemisphere.

The daily issue of a chart of this kind, thus issued for the first time by the United States, was without a precedent in history. It exhibited the co operation, for a single purpose, of the civilized powers of the world north of the equator.

Actinometry. — I. — Importance to Agriculture.—It is well known that the ordinary observations of temperature have only a very general relation to the growth of plants, which latter depends upon the direct action of the sun's rays; this is especially true of the ripening of grains, fruits, and vegetables, and some means of recording the direct effect of the sun's rays has long been a desideratum to the student of the relations between agriculture and meteorology. The simple apparatus, known as the conjugate thermometers of Arago and Marié Davy has, by experience, been found to fairly answer the necessities of this study, and 20 Signal Service stations have been selected as proper to be furnished with this apparatus. The results of observations at these will doubtless materially contribute to the decisions of questions relative to the adaptability of the respective sections of the country to certain grains, &c. The bearing that these observations have upon agriculture is illustrated in translations by Professor Abbe from recent European periodicals.

But, beside the important bearing of actinometric observations upon agriculture, they are considered of fundamental importance in the study of meteorology itself. I have, therefore, supplemented the conjugate thermometers by ordering an absolute actinometer, as invented by Violle, by means of which the total quantity of heat received at any one time and place is determined.

II.—Professor Langley's Expedition to Mount Whitney to Study the Absorption of the Sun's Heat by the Atmosphere.—The importance of this subject, mentioned in the preceding paragraph, justifies the most thorough examination of the questions—What becomes of the solar heat received by the earth's atmosphere, how much of it is absorbed or retained in the upper air, where it has an important office to perform, and what part reaches the surface of the earth where its effects are equally manifest? According to the recent researches of Professor S. P. Langley, aided by the delicate "Thermo-Electric" apparatus, devised by him, the amount of solar energy that is absorbed in the upper portions of the atmosphere is vastly greater than has hitherto been suspected, and, as the questions raised by his investigations could best be answered by means of observations made on the summit of high mountains, I have considered it my duty to further the solution of these fundamental questions by furnishing him every facility in my power to make the necessary observations. To this end Professor Langley and his delicate apparatus have, with your permission, been transported to the summit of Mt. Whitney, California, where he now is, at an altitude of 15,000 feet, and the observations made by him will, undoubtedly, determine the questions that have been raised.

METROLOGY.

II.—The Metric System.—In general the laws of the United States legalize the adoption of the metric system, and a growing disposition is believed to exist favorable to its use when necessary. It would seem that the work of the meteorologist is almost doubled by the labor involved in the mutual conversion of English and metric measures, and as the metric system is one thoroughly rational and well grounded in every step of its

development, and as the accuracy of its standards surpasses that of the English system, it is evident that in the meteorological work of this office, whose measures of to-day should be perfectly comparable with those of a century hence, an advantage would result from the adoption of this system of measures, which is in fact now used by meteorologists of all the world, except a portion of those of Great Britain and the United States. Nothing has contributed more to illustrate the intrinsic value of this system than the establishment in 1875, by the United States and other Governments, of the International Bureau of Weights and Measures.

As the metric system is fully legalized by the action of Congress, is taught in most schools, and is very widely adopted by architects, chemists, naturalists, engineers, the United States Coast and Geodetic Survey, the Internal Revenue, Post-office and Treasury Departments, I am, therefore, led to anticipate that it will ere long be incumbent upon this office to also adopt that system, at least in its scientific meteorological work.

The question is, however, one which I propose to refer, through you, to the National Academy of Sciences, as the adviser of the Government in science.

III.—Standard Time.—The importance of securing simultaneity of Signal Service observations has made it an object of solicitude as to what means are practicable and best in order to attain this end. Hitherto it has been the custom to instruct the observers to keep their clocks so regulated as to indicate local time, but on account of the great variety of times in use in many localities, much uncertainty has arisen as to what should be called the local time of the locality; thus, for instance, in New Haven the time ordinarily used has been, for many years, coincident with that used in New York and New Haven R. R., and is, therefore, several minutes slower than the proper time to its own meridian. Among the voluntary observers of the Signal Service, cases have occurred in which the railroad times to which their clocks were regulated, differed by ten or twenty minutes from the correct local time which it was supposed they were using. These discrepancies are so exceedingly annoying in minute studies upon thunderstorms, tornadoes, auroras, earthquakes, meteors, &c., that I have not hesitated to take every practicable step toward the attainment of accuracy and uniformity. Accordingly, in the new Instructions to Signal Service Observers, no local times will be recognized, but only the Washington time, as telegraphed from this office. It is very possible that the Washington time so telegraphed will, on some future occasion, be regulated by the 75th meridian, west of Greenwich. In order to promote the distribution of standard time, the Signal Service has, for some years past, had charge of the time-ball at Boston, and I propose to extend this service as far as possible, in accordance with the terms of the accompanying circular letter.

In order to answer numerous questions relative to time-balls, a letter of inquiry has been sent to astronomers having experience on this subject, and this, with their replies, has been embodied in a professional paper which includes a very full description of the Boston time-ball by Sergeant Pursell, in charge of that station.

Judging from expressions of interest in this matter, there seems no doubt but that the country, generally, would welcome any attempt on the part of this service, to distribute standard time signals, in connection with its daily weather and river reports; but in the distribution of such signals, over so wide an extent of country, it is important to decide what meridian is to be adopted as the standard.

PERMANENT CORPS.

At the proper time, Congress will be asked to increase the Signal Corps by the permanent addition of a sufficient number of officers to obviate the necessity now existing of calling for permanent details from regiments. The existing plan is very objectionable, since colonels have a plain right to the services of their officers, while officers of regiments, who have served a long time in the Signal Corps, on account of the special character of their work, are indispensable to it, and, from length of service in it, have a tacit right, and have received encouragement to look for permanence in it. Unless this plan is adopted, the duties of the Signal Corps, now so enlarged, cannot be

performed in the efficient and acceptable manner imperatively demanded. In addition to this class of officers there are others I deem it my duty to call to your attention. As in all corps of highly a scientific character, it has been found necessary, from the inception of the Signal Corps, to engage in its service civilians of a high order of scientific attainment, and who are known as professors. I find at the head of these Professor Cleveland Abbe, to whom the corps and country are under very great obligations, and it is recommended that he, with the other civilians now serving, be provided for by law, without any increase of pay over what they now receive, as is done at the National Observatory and in the Coast Survey.

I will also ask authority for the addition of a permanent party of forty men at Fort Myer.

It is believed that the pay now provided for the men of the Signal Corps is ufficient to attract the young graduates f the higher institutions of learning of he country, and an effort is being made o recruit the corps from such sources, with good reason to expect success.

The very great value of the meteorological and other data existing, and rapidly accumulating, in this office, exosed to destruction by fire and the great inconvenience of the present arrangements for the work, spreading as it has done into five different buildings, will make it imperative during the coming year to inaugurate a plan for obtaining a single building which shall be fire-proof, with capacity and arrangement suitable for the purposes of the office of the Chief Signal Officer.

CONCLUSION.

In closing my report, I must again refer to the fact that in addition to the statement of progress during the year, much must appear in each report that has already been noticed in previous years, since similar facts in organization and service will receive similar descriptions. The favorable action of Congress has yearly aided the progress of the Signal Service. The nature of its work makes it deserving of a hold on the esteem and affection of every household.

It is hoped there may be no failure in the appropriation for the Service of the amounts estimated for, which have been carefully and economically considered.

The advancement of the Service has been accompanied by continued and satisfactory success. The popular confidence and support have never been impaired and the scope of its usefulness increases with each year.

THE PRESENT CONDITION AND HOPES OF ARCHITECTURE.

From "The Builder."

If the English lover of the Græco-Roman and Italian columnar style feels surprised at the existence of dissatisfaction with this architecture evinced by the oft-repeated complaint of our want of National style, he must feel infinitely more so on discovering that a similar dissatisfaction with the style exists among the Italians themselves; which is the fact, if the declared persuasion of an eminent critic (Signor Camilla Boito) of the necessity for a new style, and attempt to invent one, together with his being allowed opportunity of embodying the result in important buildings, are to be taken as an indication of the public feeling.

Let us consider what the columnar architecture is, which has come down to us through many hands, and the foreshadowing of which formed the material grandeur of the early and renowned capitals of the world—Nineveh, Babylon, Persepolis — which was the glory of Athens, the magnificence of Rome; and for the embodied relics of which at the revival of art the greatest architects of Italy dug as for hidden treasures. The classical columnar ordinance of the Greeks and Romans I look upon as the essential nucleus or framework of the architecture of the world, for which we can imagine no substitute, and which must have appeared had the temple solemnities of Egyptians

and Greeks never required it. It lay, a divine creation, like geometry or analysis, in the womb of chaos, and must of necessity have been called forth by the first imaginative and cultured people. It is, like the mathematics, rather a discovery than an invention of man. It is not occasional and peculiar, but symbolical and universal. Whatever new building material was introduced into architecture, or whatever material becomes dominant, the colonnade will not become obselete. The simple and natural beauty of insulated columns, the magic of peristylar perspective, must ever charm the imagination of the educated and uneducated, the young and the old. The exclusive admirer of the Gothic should remember that that style is a lineal descendant of the Classic, and owes to the Classic its most pleasing features. The most beautiful Gothic cathedrals are those that show most reminiscence of the colonnade or round columns, a dearth of which always produces a harsh, liney appearance.

The same may be said of the Byzantine, Saracenic, and other styles. In fact, in the Greek temple of Corinth were lodged the germs or principles of the whole architecture of the world, as are the rudiments of the future plant in the seed. For this reason it is that in treating of the position and hopes of architecture I confine myself chiefly to classical, and not from any narrowness of view and aim, or lack of sympathy with the other beautiful and interesting, and equally true phase of it.

You meet with the colonnade, or anticipations or reminiscences of it, everywhere—in the Hindoo and Buddhist temples, and cave temples, and in palaces, tombs, and mosques of all Mahommedan lands. Architectural ambition has almost always embodied itself and broken forth in columnar grandeur; as if the beauty and capacity for sublimity of groves of columns had smitten the imagination of every people possessed of one on the earth.

It is absurd to go into raptures over the Parthenon and be, at the same time, indifferent or opposed to the columnar style, because all that charms us in that building belongs to the columnar style, every example of which is susceptible more or less of the beauty and harmony of the Parthenon, which, denuded of its sculpture, remains exquisite architecture, proving it, like female loveliness, independent of the foreign aid of ornament. But the quality of being self-dependent or having need of nothing bears most analogy to the excellence or perfection of the Supreme Being, and therefore most divine. It is an attribute of the style that eminently fits it for the solemn temple, which it will as truthfully form as the gorgeous palace. And if it cannot express so vividly the hopes and aspirations of the Christian as the Gothic, its abstinence from the attempt is to the preservation of beauty in its sacred embodiments, and renders them a truer reflection of that grace of external nature which is the veil of the Eternal Cause, and nearer to the fashion of the shrine which we may suppose He would himself have built to His worship; more likewise in unison with the holy and beautiful breathed from the Lyre of Inspiration.

Let no one suppose the columnar architecture a mere stereotyped formula of three or four columns; for the scope for variation on their capitals alone is infinite. To it belongs the dome in its utmost chasteness and grandeur.

This is the style which certain architects and critics would supersede by some new invention.

The sudden appearance and general introduction of a new style has no precedent in the history of architecture, even among the most artistic nations. We can trace every known style back to its origin and descent from one or more parent styles, generally to two, except the Pelasgic, Egyptian, and Assyrian, their origin being lost in the night of time, and no remains of earlier styles having been found. New styles, it is true, have been evolved spontaneously and slowly by the mingling of two others, and may be again—the growth of similar circumstances; but no style was ever called out of chaos. To reject the columnar ordinance of the Greeks and Romans, and seek for new elements, is as absurd as to reject all that has been wrought out in philology and literature, and go back to Cadmus or to hieroglyphics. He who does so places himself in a worse position than the first nations. He is like a poet by nature, endowed with the highest gifts perhaps,

"The vision and the faculty divine
Yet wanting the accomplishment of verse."

He forgets, or is ignorant, that architectural creation does not consist in calling architectural designs from nothing; that it matters not how much an architect is indebted to other men for his materials, if he combines those materials according to new affinities and "adorns nature with a new thing." Nor need he be surprised if any architectural style which is the child of his own brain, does not find favor, or that it results in something the embodiments of which in buildings it would be flattery to call architecture. He must, indeed, soon discover that his only chance of competing with the past in architecture is to avail himself of the labors of his predecessors, and adopt the columnar ordinance of the Greeks and Romans, or the arcuated system of the Mediævalists.

Than such movements and the criticism, English or Italian, that leads to them, nothing can be more mischievous; for the faith of the student in the truth and capability of the style, which it is calculated to unsettle, is essential to his progress; and architectural students are in vain exhorted to diligence and enthusiasm in the pursuit of their art when they are left in doubt by conflicting criticism what phase of it to pursue, or whether any phase of it is worthy of their acceptance. Faith is as essential in art as it is in religion; for "if the trumpet give an uncertain sound, who shall prepare himself to the battle."

But for this criticism there would be little need of inciting to zeal in the fascinating study of architecture. As in religion, unshaken faith would be followed by love in the breast of the student for one or another of the styles of the day that solicit his attention, according to his natural or acquired predilection.

Though, on the other hand, there are not wanting critics who, from dissatisfaction with present practice, or late efforts at originality, counsel the mere adapting the old productions of this style to modern purposes, and even go so far as to suggest copying, I will not suppose that the descendants of the ancient Greeks and Romans—men with more or less of the blood of Phidias and Praxiteles in their veins, for such are the modern Italians—are ignorant of the right use of architectural examples to the architect, or unable to grasp the true principles of their combination. I cannot but suppose that Italy contains hosts of men with sufficient imagination—the vital quality in all art and artists—to fuse into other harmonious examples the same elements from which those elder buildings were composed; in other words, of making the same use of the elements so abundantly placed at their command that Sansovino and Palladio made; which does not need a succession of eminently gifted men. Men of ordinary abilities would suffice if they have any reasonable depth of artistic feeling, which gives a power and insight to the intellect it would not otherwise possess.

Ancient examples are to be neither copied nor adapted; both practices are unworthy of an architect. Those who recommend them forget, or are ignorant of the epochal, local, and ethnographic nature of architecture—the relation it bears to its own age and country. Ancient buildings cannot be examples for all times and places. They are to be mentally dissolved and recombined into other forms—decomposed and recomposed.

Nothing is more natural than for the Italians to adopt this columnar ordinance, for it is their own rightful property—the bequest of their forefathers. Italian architecture is not strictly a revival or resurrection of the Græco-Roman architecture, as it is generally supposed to be, for that style never died at Rome, which, owing chiefly perhaps to the sacred character of the Pontiffs, preserved in a greater degree than any other city the traces of ancient civilization. The night, it has been said, which descended upon her was the night of an Arctic summer. The dawn began to reappear ere the last reflection of the preceding sunset had faded from the horizon. A stream, narrow indeed, but pure, of that architecture came down embodied in the Christian basilicas at Rome, which are not Romanesque, but Roman, whence it issued into all the countries of Europe. Certainly it was not revived in the sense in which Greek literature or painting or sculpture was revived. Greek literature had been lost to Europe for centuries, and survived only among the Saracens and Eastern Romans, from whom it was first recovered in the thirteenth century. Greek

painting had been lost till recovered by Cimabué and Giotto from the Byzantine school; so had sculpture, of which Pisano was the modern restorer. But Græco-Roman architecture, alive from classic times, was present in all its beauty at the capital of the world when it was wanted, and, blended with Italian Romanesque, contributed to the inspiration of the Venetian, Roman, Florentine, and other varieties of the Italian in the sixteenth century.

I can imagine nothing more natural or droper than the resumption of the ancient architecture by the Italians, nor than the general course which it took in Italy in the fifteenth and sixteenth centuries. Let us glance at its history. It is probable that Brunelleschi was the first to infuse a purely antique spirit into his works, among which may be cited the cupola of the cathedral of Florence, the erection of which opened the way to the greatest architectural enterprises of modern Europe, the Church of the Holy Ghost, and the Pitti Palace in the same city. He was followed by L. B. Alberti, who emulated the achievements of his predecessors, and in some respects excelled them. The churches of St. San Francesco at Rimini, and of St. Andrea at Mantua, with the Palace Rucellai at Florence, are among the best of his works. Michelozzo, a scholar of Brunelleschi's, and other Florentine architects, followed Alberti, and were seconded in developing and applying the style by Bramante, who had practised in the former one. The Belvedere Court of the Vatican, the Court of the Loggia, and the Sora Palace at Rome, are specimens of his graceful manner. Peruzzi showed greater freedom in the use of his materials, as witness the palaces Farnesina and Massimi at Rome, and was seconded by Antonio Sangallo and by Raffaelle, in whose hands and those of Michelangelo, Vignola, San Michele, Sansovino, Palladio, and others, the style of ancient Rome was restored in all its grace and grandeur, and so expanded by additional elements, in its application to new uses, as to be rendered a distinct style, and in some respects a more consistent one than its antique parent or prototype.

No trail of the serpent seems to have been descried on it by any one of the architects just named, and many of them are men of strong religious feeling. They probably remembered that it had been in the service of Christianity, in the Basilicas before mentioned, since the time of Constantine the Great, long enough to atone for its guilt, if it had incurred any, in the service of a false religion; if, indeed, they did not feel that there is a holiness in real architecture, as in all true art, which no alliance with heathenism or anything else could take away. Such was the course of architecture in Italy, and the career of its most eminent professors—the greatest architects, painters, and sculptors of the most accomplished age of the world since that of Pericles.

Now, if the human heart and imagination is the immediate fountain of all poetry and art, it is exceedingly absurd to suppose that the artistic instincts of such men, including one I have not yet named, Leonardo da Vinci, who, being an architect, was also concerned in the movement—a painter, sculptor, poet, the greatest intellect of the fifteenth century, and seemingly of universal and superhuman knowledge—should have betrayed them into a wrong path—a path in which originality and progress was impossible—and that another galaxy of great artists should have blindly followed them. I conceive that such men would have gone right by the mere force of their imaginations, and have been more likely to make a stride in the right direction than to slide into a wrong one. I conceive that such men as Da Vinci, Michelangelo, and Raffaelle, whose names are almost synonymous with beauty and sublimity—who had grasped the whole realm of design, and were almost the inventors of chiaroscuro in painting—would leave examples of a proper union between the three arts, and advance the style in every respect as no mere architect could. We should remember that artists such as they—of the highest order that ever appeared on earth—have always uniform, well-balanced minds, with judgments commensurate with imagination. If it be argued that true architecture is that on which its authors have impressed the leading thought of the age, I answer, the revival of the productions of classic antiquity was the great thought of that age.

But this style is greater than its examples; and its highest reach of monumental grandeur or utmost possibility is

not to be judged by its most important embodiment—I mean, of course, that most costly and ambitious structure ever reared to the honor of Christ—St. Peter's Church at Rome—which, from some cause or other, does justice neither to the capabilities of the style nor the genius of the great architects employed on it, The exterior, of which alone I am speaking, has not a single detached column about it, and is, therefore, deficient in relief.

This church has been overpraised both by Byron and Lamartine, the latter more extravagantly when he says that in St. Peter's Church Michelangelo has clothed the idea of God with all the beauty of which it was capable, which is not true. The front of it was susceptible of such treatment by means of colonnades as would have rendered it infinitely more beautiful. Never was the homely proverb, "Too many cooks will spoil the broth," more strikingly verified than in the design of the Pontifical Church of St. Peter. The least eminent of the architects employed on it ought to have produced a superior principal façade, which lacks those mighty and vigorous masses of shadow without which, as Ruskin justly remarks, no building can be truly great.

Great mistakes, I grant, may be attributed to many of the leaders of the movement, and to none more than to him whose name has become identified with Italian architecture—Palladio, who, it is certain, has been over-estimated by many eminent critics, as Quatremère de Quincy, Hope, Beckford, and, strange to say, by the great poet and philosopher, Goethe, who represents him as ever seeking to embody some "great image which he has carried in his soul," a scarcely correct notion of architectural generation. He too often forgot that the beautiful in architecture springs out of the useful, having left instances among his works of unbordered windows, and of the columnar order constituting the whole of the architecture, which could, therefore, be separated from the building, though the better principle had been exemplified in the Florentine school. Palladio, however, oftener pursued architecture in the right spirit, and has left works, in the true sense of the word, original. He had no notion of merely reproducing Roman buildings, nor even adapting them to his purposes, but strove to mould the antique elements into accordance with his own ideas. He seems to have begun his career with the persuasion that the style would stoop to the humblest purposes of life, and that in extending it to such he was only continuing the application of their architecture begun by the ancients themselves. His predecessors probably considered it as fitted only for churches, palaces, and public buildings; but Palladio's varied works at once proved that its applications were unlimited.

But be his faults or mistakes what they may, they are no reproach to the style which was practised in his time, the productions of which, in not a few instances, while they are not unlike any former works, and therefore original, are amongst the most successful structures ever reared for harmony and beauty of form, and refinement and elegance of detail; being the issue of a fruitful imagination under the guidance of a pure and sound judgment.

Brighter and more enchanting forms than any that have yet appeared may be embodied by it, brought from among the golden visions that lie mirrored in the fairyland of the imagination; especially of the gayer and more aërial kinds, which will be admitted by him whose eye, bodily or mentally, has ranged over the creations of a style which is an offshoot of it—the Saracenic—in various countries of the East, more especially the exquisitely lovely scenes of fairy splendour in Hindostan, which are frequently aided in their designed character by a material of such purity and brilliancy that the whole resembles a flood of moonlight.

More artistic and higher combinations of Greek and Roman elements than Palladio or his predecessors or followers thought of are possible, and, what is more, are really called for by utility in some of the highest class of works. The great defect of the trabeated system is, that it is only fit to form the façade of a building to be entered singly, or in single file, and will not form the lofty and broad entrance required by a palace, or church, for processions, without injury to its beauty; and while the colonnade is necessary to the highest grandeur, the arcade is essential to a great entrance door or gateway. It gives the largest single opening—an opening as broad and high as can be required.

But I believe the two principles can be combined in the formation of a grand entrance consistent with artistic harmony and unity; that is to say, two colonnades may, with some careful management, be combined by means of a connecting archivolt springing from entablature to entablature, into one great and harmonious feature, embracing a central entrance, which may be as great and lofty as could be desired. The side intercolumnar spaces would be subsidiary entrances, and highly useful and pertinent; or, where not required for entrances, would form framework for sculpture. The breadth of entrance thus secured seems highly desirable in any public building, whether public processions are to be provided for or not; and the mode of obtaining it here suggested is worthy of consideration for its increase of combined fitness and beauty. It would be a new kind of coalition between the Greek and Roman or Romanesque styles.

The Italian style as it spread from Florence, where it rose, to Rome and Naples on the south, and to Venice, Genoa, and Milan on the north, accommodated itself to the natural, political, and social peculiarities of each city; most notably to those of the sea-girt and sea-intersected Venice, and so became the chief ornament of that gem of cities. It showed it could breathe a still more northern air, that of England, wherein a few works could be found that, for purity, harmony, and appropriateness, will compare with any of a corresponding class in Italy; along with abundant proof that no elements will so satisfactorily weave into the continuous houses or shops we require in our streets, with regard both to convenience and beauty. Indeed, its merit and value lie not in its sageness and beauty only, but in its organic vitality and possession within itself of the principle of future expansion and application to all the multiform and accumulating demands of human life. It will as truthfully form the features rendered needful by rain and wind and cold as those required by sunshine and heat; in other words, it is a Northern as well as a Southern style.

It will, doubtless, form in perfection every species of public and private edifice called for by the various institutions of every country of Europe, including engineering buildings, bridges, viaducts, &c., along with strictly architectural ones, without sullying its classic purity, but rendering them musical as Apollo's lute; for those columnar elements are susceptive of the utmost grace and refinement of which structural art is capable.

Such failures as the exterior of the British Museum are no disparagement of the style, for that is a magnificent display of its elements, which, owing to timidity or want of imagination in the architect, were not worked up into a design. It is not answerable for that, nor for another remarkable instance of undigested material, which, in justice to architecture, should be pointed to, viz., the new Houses of Parliament at Vienna, a view of which was given some four years ago in the *Builder*, and now, I presume, approaching completion; which is nothing more than a number of decorated blocks of building in mechanical conjunction, which, though forming a magnificent architectural group, have no claim to be considered a work of art.

Nor are those modern buildings, which are externally reproductions of the Greek peripteral temple, such as the Town Hall at Birmingham, the Church of the Madeleine and the Bourse at Paris, the Walhalla at Bavaria, to be considered as anything but libels on the character and resources of the style, which is capable of infinite variety on the Greek type, and greater display of columnar richness and grandeur. The periptery, unless redeemed by Parthenon-like perfection of line, by variation of capitals in the same façade, and high-class sculpture in the pediments and friezes, is a monotonous spectacle. Klenze in the Walhalla could have produced a national temple that would, in point of composition, have been an advance upon it.

What in each country this style requires is to be made as much as possible to form, not adorn merely, windows, doors, porches, chimneys, and other features required by the climate, in emulation of the Gothic, which grew up and around—identified itself with—essential features, as in the window, which was the most useful feature, and became the most beautiful, the useful and beautiful growing up in conjunction; which must be always the most pleasing, like that rarity —a virtuous mind in a beauteous body.

As to the chimney, it seems a providential provision for relieving the sky line, and giving intimation without of the home life within.

The so-called Queen Anne movement, in search of greater picturesqueness, seems to me to be uncalled for. Holland is useful to feed the imagination of the architect, which must ever be indebted to reminiscence—a fact the ancients meant to indicate by representing the Muses as the daughters of Memory. Inspection of the picturesque buildings of Holland is calculated to make his own mind more prolific. They are seed cast therein to bear fruit in his own works. But with the highest reverence for the art genius of the Dutch of the seventeenth century (most brilliantly manifested, however, in painting), I think it is unworthy of English architects to introduce and set up here a style from Holland. It is, to say the least, going to the huckster's shop instead of the warehouse for our provisions.

If we are as truthful and independent in our treatment of the columnar architecture, in acclimatizing and nationalizing it, as were the Dutch architects, and withal pay due attention to the securing a good and lively outline, and light and shade in designing, and are careful ever to make a beauty of necessity, we shall be sufficiently picturesque. Time and weather and accidents are agents in the production of that extreme degree of picturesqueness which the landscape painter delights in; and their effects are not to be anticipated by the architect.

When I contemplate the beauty and capacity of the style in question, and of the styles descended from our forefathers in their respective embodiments—the result of the highest efforts of the wisest nations in the way of architecture, forming a mine of elements such as neither Greek nor Roman ever knew, and put into the hands of all by means of engraving and photography, I feel more disposed to exclaim, in the words of the Psalmist, "The lines have fallen to us in pleasant places, and we have a goodly heritage," than to complain of the want of a national style. For if these are not our national styles whose are they? A question history is best able and has most right to settle, and she intimates, I think clearly, that in working in an adapted or modified Italian style we are truly succeeding and following the great nations that have preceded us in civilization—Egyptian, Etruscan, Greek, ancient and modern, Roman, Venetian, Pisan, and Florentine—in the way we should go—the providential way, with increased and accumulating means and opportunities of arriving at successful issues. Our difficulty seems to me to be not in having no national style, but in having two national styles—the style we inherit from classic antiquity along with its civilization, and that bequeathed by our forefathers—a style to which many hearts cling, and not without cause. We have two phases of architecture, so beautiful that we cannot turn our backs upon either, and may say, in the words of Gay's "Beggars' Opera"—

> "How happy could I be with either,
> Were t'other dear charmer away!"

and I question whether any former nation would not have felt and acted in a like manner.

If the Gothic would borrow a little more of Greek refinement from her Oriental sister, the Byzantine style, of which she is highly susceptible, and fully recognize the change in the world and in her own circumstances since she fell asleep in the sixteenth century; and if the classic at the same time were fully nationalized, they would assimilate so far that there would be but little discord in our towns arising from the pursuit of both.

Whether they would or not, neither Gothic nor Classic can ever be abandoned in favor of a new style; for no new style will ever be invented or generally followed. We had better, therefore, accept that fact, and pursue the styles we have, which, indeed, seems the providential course. Each style, however, should have its separate followers, as no man can with heart and soul follow both; and the student should be taught to make choice of one or the other, which would be most favorable to his growth in artistic feeling and power. It was, therefore, wise in the Royal Academy Professor in his recent lecture to discourage the following a plurality of styles. Inigo Jones was, doubtless, right in appending a Corinthian portico to old St. Paul's cathedral. He could put some feeling

into that, but he could probably have put none into a Gothic porch, and a living dog is obviously better than a dead lion.

I conceive of architecture, like the graceful figure of her on the tomb of the Italian architect Sada, engraved in the *Builder* not long ago, as flourishing in the bloom of an immortal youth and beauty—for such the rose of juvenility must intimate on the brow, pensive though it be, of a lady who, if her first advent on earth was in Egypt, and the sanctuary of Karnach was her firstborn, must be over 4,000 years old. I grant that she has betrayed great eccentricities within the last century, not only in England and the North, but in Italy, the birthplace of her most illustrious modern followers. But I strongly suspect that her aberrations are in a great measure owing to the conflicting opinions and advice of her councillors (the critics), whose utterances have been, in too many instances, merely empirical, and too seldom based on the spiritual and emotional nature of architecture and art. Instead of trying to breathe into her some sparks of her ancient fire, by reminding her of her glorious antecedents and achievements, and especially of her labors of love in ancient Greece and Mediæval Europe, through which she has helped the cause of civilization in the world, and even exalted the idea of religion, they have of late been prophesying evil against her, insinuating that she is in a decline, and all but defunct; one, otherwise an eloquent and judicious critic, even talking of mourning in sackcloth and ashes over her degradation. A glance over the chart of her history will show that she is, like ourselves to a great extent, the creature of circumstances—the sport of accident; and if so, surely no circumstance, no accident, can be more injurious to her than such conduct on the part of her friends, concerning whom she might well, with the ancient Roman, cry out to the Gods, "Oh, save me from my friends!"

What she has once done she can do again. The aliment on which she lives is as nourishing and the fountains of her inspirations are as lofty as ever they were, and more unfailing. Of a soul-born, spiritual substance, she is necessarily indestructible, and exempt from the common lot of obsoleteness:—

> "Age cannot wither her, nor custom stale
> Her infinite variety."

Like her sisters, Poetry, Painting, and Music, she has fresh fields and pastures new and delightful for ever stretching out before her, through which she may

> "Still walk in beauty like the night
> Of cloudless climes and starry skies."

But I have long been of opinion that her gait and mien would be more majestic if she were not so much perplexed with matters which do not properly belong to her, and which might very well be intrusted to another and more material agent, called Practical Building or Construction, who would be held responsible for the faithful and durable embodiment of her images of beauty. She should be on intimate terms with, nay wedded to, Constructive Science, and her conceptions should be the fruit of the union; but beyond the full mental development of every part of her offspring as to form and hue in all their minutiæ, she should not be expected to operate. All the rest ought to be left to her deputy, or subordinate, Practical Building, educated expressly for the post, who should govern and direct his invaluable servants —Masonry, Bricklaying, Carpentry, Joinery, Plumbing, &c., and become answerable for their honest service. I do not mean that she (Architecture) should shirk any mind or heart work whatsoever, but simply relieve herself of all that is merely mechanical, and that could be as well or better done by another, and reserve her strength for higher work.

I know nothing more that is wanting beyond what I have directly or indirectly pointed out to render her winter of discontent a glorious summer but sincere and earnest followers who, like Michelangelo, would work for the love they bore to her, and not merely for the gold they could wring from her. Some gold they must have, and some gold she will doubtless give them, but the "accursed thirst of gold," as the prince of Latin poets calls it, must not be their inspiration. It is not too much to say, "We cannot serve her and Mammon," a truth which it is important for those who have her interest at heart, and are anxious to remove all stumbling-blocks from her path, to bear in mind. A community of her true followers, wheresoever born, bound

together by sincere attachment to her for her own sake, would constitute the true modern Freemasonry, and be a worthy successor to the Mediæval; the proper successors or continuators of the Freemasons being surely architects and skilled and scientific builders, architectural sculptors and carvers, and even earnest foremen and workmen, rather than the miscellaneous fraternity (miscellaneous as regards individual professions) that now bear the name.

That such a community of various ranks of earnest men, each pledged and incited by every high consideration to the service of their beautiful mistress, through evil report and through good, nothing, I think, would be better calculated to meet the present exigency, and awaken in the profession, or at least in the breasts of all susceptible of it, some sparks of the pure religious - and - art spirit under which the Mediæval Freemasons worked; while the achievements of the Freemasons, and Greeks, and Italians—that is architecture in its highest examples and possibilities—would be likely to seize upon and inflame their imagination, and become an ideal standard of aspiration. Such an institution would like chivalry, have a purifying and elevating influence on the character of each member.

Within such an institution I can imagine the workmen sympathizing in the emotions of the architect, and having an æsthetic part in the adornment of his works.

THE PHYSIOLOGICAL EFFECTS OF COMPRESSED AIR.

By C. M. WOODWARD.

From Advance Sheets of "History of the St. Louis Bridge."

VERY little was known of the peculiar effects of compressed air upon men when the sinking of the East Pier of the St. Louis Bridge began. The observations of European engineers where it had been used were generally limited to the effect upon the human ear. In 1852, Mr. J. Hughes, assistant engineer at the Rochester Bridge, England, noted that men at work in compressed air had "a remarkable increase of appetite for food." Respiration, he says, was "slightly affected," and when the transit of the air-lock was rapidly made, there was some complaint of headache. The greatest depth under water was 61 feet.

In 1861, Mr. Robert P. Brereton, one of the assistants of Mr. Brunel at the construction of the center pier of the Royal Albert Bridge at Saltash, England, stated before the Institution of Civil Engineers some of their experiences. The maximum air-pressure was 40 pounds above the normal; usually the pressure was much less, as the water in the main cylinder was kept down by pumps. Mr. Brereton said that at first his men worked too long at a time, and on coming out they were slightly paralyzed, but in two or three days they quite recovered. With three-hour shifts the men could remain at work for several months consecutively. (Brunel was about two years in establishing his pier.)

The eminent engineer John Hawkshaw said that at the Londonderry Bridge, "where 75 feet pressure was experienced, there *had been some casualties.*" One of the effects produced by the air-pressure was that the joints of some of the less robust men began to swell.*

In 1865, Dr. A. Magnus, of Konigsberg, published the result of his observation upon the effects of compressed air in the caisson of the bridge pier at that point.†

"It has been shown in former works of this kind (at the mines of Douchy, for example) that the human organism may endure a pressure of four atmospheres without harm, but that it frequently happens that sickness is caused by a rapid *diminution* of *pressure.* So far as I know," he continues, "there are no German publications about this matter, though certain Frenchmen speak of them." The rules he gives have reference only to the ear, when entering the air-chamber.

In like manner, all who had written on

* Proceedings Inst. Civ. Eng. Great Britain, Vol. XXI.

† "Schriften der physikalisch-ökonomischen Gesellschaft." VI. Jahrg., 1865.

the subject had assumed, from the comparative immunity with which men worked under two, and even three atmospheres, that no harm could arise from four or five atmospheres.

Reference has been made in a previous chapter to the visit of Mr. Eads to the bridge-building at Vichy, in 1869. Mr. Audernt, the resident engineer, had put down forty piers by the method of compressed air, but his deepest had been only 75 feet below the surface of the river (the Po at Placenza); but neither he nor Mr. Moreaux (the "builder of a thousand bridges") could give any definite opinion as to the practicability of working men at a depth such as the East Pier of the St. Louis Bridge would reach. In England, Mr. Eads conferred very fully with Mr. Brereton. It is probable, however, that his own diving-bell experience made him the best judge of the effects of air-pressure, and yet even he had no adequate idea of the peculiar results actually experienced. As he himself said, no similar work having penetrated to so great a depth, he was left without any benefit from the experience of others, either in guarding against any injurious effects of the great pressure upon the workmen and engineers subjected to it, or in relieving those affected by it.

With this brief introduction, I proceed to give as full account of all matters relating to compressed air during the building of the St. Louis Bridge as my space will permit.

Until the cutting-edge of the caisson of the East Pier was nearly sixty feet below the surface of the river, there was no serious drawback to working four, or even six consecutive hours in the air-chamber. The men worked eight hours consecutively, coming up, however, to lunch at the end of four hours, till the caisson was down 42½ feet. Then, one of the foremen being sick, it seemed best to change the day's work to two watches of four hours each, with a rest of eight hours between. This scheme was followed till February 5, when, the immersion being 65 feet, a day's work was changed to six hours, consisting of three watches of two hours each, with two-hour rests.

The first effect noted upon the men was an occasional muscular paralysis of the lower limbs. This was rarely accompanied with pain, and usually passed off in a day or two. As the depth of the caisson increased beyond 60 feet, the paralysis became more difficult to subdue. In some cases the arms were involved, and in some the sphincter muscles and the bowels. In the severer cases the patients also suffered much pain in the joints and in the region of the stomach. Many of those affected suffered no pain whatever.

So long as the affection was painless, it was not regarded as a very serious matter. A workman walking about with difficult step and a slight stoop was at first regarded as a fit object for jokes, and cases of paralysis and cramp soon became popularly known by the name of "Grecian bend." In some cases there was paralysis of the nerves of sensation alone. The numbness generally extended over one or both legs, although it occasionally applied to the arms and face.

The common remedy was the rubbing of the affected parts with oil or liniment of some kind. A certain "Abolition Oil" gained great popularity: according to Col. Roberts, it "worked like a charm."

In cases of entire or partial paralysis of the limbs, a battery was frequently used, but the records show that the remedy was thought of little value. A more efficient means for relieving pain was the warm bath, and it was repeatedly used for the earlier severe cases. Subsequently, Dr. Jaminet forbade its use, though it was a first remedy at the City Hospital.

A fancied safeguard was the use of galvanic bands or armor. At first, in the opinion of the superintendent, the foremen, and the men, the armor gave remarkable immunity, and all the air-chamber men of the East Pier were provided with it at the company's expense. The bands were made of alternate scales of zinc and silver, and were worn around the wrists, arms, ankles, waist, and also under the soles of the feet.

As the pier descended into the sand, the distance from the top of the pier down the winding stairs to the air-lock increased as well. A depth of 70 feet made it necessary for each watch on its exit from the air-chamber to climb about one hundred and forty steps. The men were instructed to rest frequently on their way, but the request was generally disregarded. The fatigue of the ascent added not a little to the distress and prostration of those affected with cramp.

It was noticed that to one with cramps it was often a relief to return to the air-chamber.

When the immersion was 65 feet, a man just leaving the air-lock became unable to ascend the stairs. On the 15th of February, immersion 67 feet, a man suffering greatly in his limbs and back was sent to the City Hospital. From this time forward severe cases of cramps and paralysis were frequent, and several cases were sent to the hospital. The superintendent noted the fact that the sick were often thinly clad and poorly fed. One man became unconscious, and did not speak for three hours. All that they could do for him was done. He was stripped, rubbed, and wrapped in warm blankets. Mr. McComas says (in his diary) that the poor fellow came to his work with no stockings (the weather was cold), and that his clothing was very thin.

A great majority of the cases were among the new hands. In marked contrast with the number of men who were attacked at the end of their first trial was Keith, a sub-foreman. On February 20, when the immersion was 81 feet, the foreman of his relief being sick, Keith remained in the air-chamber ten hours out of twelve, and suffered no harm. Occasionally the old hands suffered, but the severe cases were new men. On February 26, nine men were attacked at once, one an old hand; none, however, seriously.

On the 28th of February the caisson reached the rock. Immersion, 93½ feet; pressure in the air-chamber, 44 pounds above the normal. The two foremen had been very active for a day or two, in their zeal to "land the caisson," and, as a consequence, while all others were rejoicing over the triumph they were groaning with aches, which did not yield to the ordinary applications. "All remedies fail," wrote the superintendent, at 5.40; "Shrieves is suffering severely." At 6.40 *he was well and out.*

For a few days the force in the air-chamber was small. Most of the workmen were affected. "It seems impossible," wrote Mr. McComas, "to keep a force up." He determined to shorten his watches to one hour. The next day the gangs were relieved every hour. There was no complaint, but the men evidently disliked being called up so often, and dreaded so many ascents of those winding stairs—100 feet high. The following day they resumed the two-hour watches. They were concreting now, and the work was hard. The gangs were small and carefully watched. Soon Mr. McComas concluded to have them work only by day—four gangs, two on and two off; three watches of two hours. The night gangs had suffered most, the explanation being that the men did not rest properly by day.

There were only a few cases from then till March 19; then they were startled. This "log" entry of Mr. McComas tells the whole story: "James Riley died to-day at 10.15 A.M. Verdict of the jury, 'apoplexy.' He had worked only two hours in the air-chamber. Came up feeling very well as he said to one of his friends. In fifteen minutes afterwards he gasped and fell over, and was dead in a few minutes. I was fearful it would have a bad influence on the men, but they did not appear to mind it in the least." This was the first death, but another of the men died at the hospital the same day. During the next few days several very severe cases were sent to the hospital, and three more deaths occurred—two on one day. On March 28, a man applied for work in the air-chamber, whom the superintendent, for some reason, refused to take. A little urging resulted in the man's putting on the armor and working two hours. Fifteen minutes after coming out he was dead. Verdict, "apoplexy," as before.

It was evident that more stringent regulations were necessary to check both the number and the severity of the cases. Dr. A. Jaminet, a regular practitioner in the city, and Mr. Eads' family physician, was employed to take charge of all the men at work in the air chamber, and to establish such regulations as in his judgment the well-being of the men demanded. Dr. Jaminet took charge March 31. A floating hospital was at once fitted up on a boat lying just below the pier. Besides ordinary accommodations, berths were fitted up in which workmen could lie down during their hours of rest.

Dr. Jaminet had been a frequent visitor to the air-chamber, and had himself felt the peculiar effects of compressed air. He had been much interested in testing the familiar law regulating the boiling-point of liquids when under pressure, and in noting the effect of the compressed

air upon himself and those who entered the caisson with him.

Dr. Jaminet had noted the men as they came from the air-chamber. Their appearance was palid and cold. In some the pulse was quick, varying from ninety-five to one hundred and ten, but somewhat weak; with others it was as low as sixty. Without exception, the workmen complained of fatigue.

Dr. Jaminet observed that the pulse always quickened on entering the air-chamber, though it soon fell to the normal pitch, and even lower, in the course of a watch.

On one occasion, the pressure being 32½ pounds more than an atmosphere, he recorded the pulse of himself and five other visitors as follows: Before entering, 81, 78, 78, 79, 79, 80. Temperature, 56° of external air. They were ten minutes in the air-lock. At the end of six minutes their pulses were 100, 88, 98, 86, 95, 90. Thermometer, 62°. Temperature in air-chamber, 48°. In twenty minutes all felt a marked exhilaration. At the end of two hours their pulses were 68, 70, 71, 69, 70, 72. Their chests expanded during inspiration normally. They spent five and a half minutes in the air lock on their return, and they felt very cold. Thermometer fell to 37° in four minutes. Before ascending stairs, pulses stood 69, 70, 69, 71, 68, 72; after climbing the stairs, 106, 104, 92, 94, 102, 99.

On another occasion, Dr. Jaminet, three strangers, and two workmen entered together. Pressure, 37½ pounds. Depth, 81 feet. The pulse record was as follows:

Before entering.....	81	75	76	80	76	82
On entering chamber.....	97	77	77	92	88	90
At end of two hours.....	64	70	67	69	68	68
On reaching top of pier...	104	90	90	100	94	96

In the air-chamber, the number of respirations increased from eighteen to twenty-one per minute, and for a time at least there was a feeling of exhilaration. The workmen, without exception, sweat profusely throughout their stay in the air-chamber, though the thermometer was often below 60°.

The air-lock was, as a rule, excessively warm when the pressure was increasing, and exceedingly cold when the pressure was diminishing.

Dr. Jaminet always complained of cold in the air-lock, returning, and severe epigastric pain about ten minutes after coming out. On the day the caisson touched the rock—pressure, 45 pounds—he remained in the air-chamber two hours and three-quarters. While in the air-chamber he felt well. In the air lock, on his way out, he was conscious of a great loss of heat, and a violent pain in his head. The air was escaping very rapidly. (The chief engineer was with him in the lock, and, as was usual with him, the discharge-cock was wide open.) At Dr. Jaminet's request, the escape of air was stopped a moment; the time spent in the lock was, however, *but three and one half minutes.*

With difficulty the doctor climbed the stairs. His pulse was 110; he was suffering severe epigastric pain, and his strength was nearly gone. He went directly ashore on the first boat. With great exertion he managed to walk from the boat to his buggy, not one hundred yards away, and clamber in. He was able to drive to his house, half a mile distant, and stagger into his office, where in a few minutes he became paralyzed. For some time he could not speak, but he retained his consciousness. Gradually he gained command of himself, but his sufferings were intense, and for three or four hours he considered his life in extreme danger. It was over twelve hours before he began to move his legs. A little later he was able to walk, but he was feeble for some days.

Dr. Jaminet made several careful investigations upon the amount and character of the waste of the human system while in the air-chamber. He found that, invariably, an abnormally large amount of urine was secreted, and that it contained unusually large amounts of urea.* It was found that the men had been accustomed to pass very rapidly through the air-lock, particularly when a "green hand" was present. This harmless fun, as it was thought, often cost the poor fellow a great deal of pain and terror, and sometimes very serious injury. Dr. Jaminet instructed the lock-tender to increase the air-pressure no faster than three pounds per minute, and to dimin-

* He estimated the amount of urine secreted during the twelve hours from 7 A.M. to 7 P.M. as, on the average, twenty-eight or thirty ounces per man, and the quantity of urea was "far in excess of the normal quantity found in the urine of a healthy laboring man, when working in the normal atmosphere." The men drank water freely.

ish it no faster than six pounds per minute.

Prior to March 31, the men had been at liberty to spend their "off" hours as they pleased, provided they promptly answered the whistle-call for their watch. The doctor now required them to lie down in the berths provided for that purpose, for at least one hour, immediately on coming up. The intervals for rest and food between the working watches (which last had been three in number and two hours each) were increased to three hours. Each man was also subject to a rigid physical examination; all old hands deemed unsuited to the work were discharged and unpromising applicants were rejected.

Under the new *regime* things promised well. At first the men were on a strike, demanding $5 a day and only four hours' work (they had been receiving $4 for a day of six hours); so there was little work in the air-chamber for some days. April 4, a new man was slightly affected; he was at work again in two days. The next day a sub-foreman (Lyon) was taken seriously ill.* Two other cases occurring in quick succession, a day's work was reduced to two watches of two hours, with a rest of four hours between.

This did not appear to mend matters much. The doctor reports that the men refused to obey orders as to the hours of rest. As soon as their second watch was over they hurried ashore, "and instead of going home to keep quiet and rest, the most of them were wasting their time in bar-rooms, or other places unfit for any man employed in such exhausting work." This strong statement shows that at times his patience was sorely tried.

On the 8th, a man whom the doctor had once rejected came with a friend, and entered the air-chamber without the doctor's knowledge. At the end of the second watch he was taken very badly with cramps and paralysis, and it was months before he fully recovered. Five more cases occurred at the East Pier up to the morning of the 13th of April, when, owing to the flooding of the top of the pier, the concreting in the air-chamber was discontinued. Only one of these cases was serious. The man was badly paralyzed and broken down. After lingering about a year, he died.

The pressure of the East Pier for several days had been 50 pounds. At the West Pier, which was now on the rock, concreting was also going on under an air-pressure of 40 pounds. A very bad case had occurred at the latter pier on the 12th. The pressure being less than at the East Pier, there was thought to be little danger, and the doctor had confined his attention chiefly to the deeper pier. The men had been working six hours per day, in three watches. A few cases had been sent to the floating hospital, but they were slight. The case on the 12th, however, resulted in death. The man was really unfit to be there. He had been a hard drinker for the last year, though he declared he was sober the day he went into the air-chamber. He worked but two hours. This *was the only death* resulting from work at the West Pier.

After the 13th, the number of men at work in the caisson of the West Pier was about one hundred. The day's work was reduced to two watches of two hours each. During the next fifteen days there were fourteen cases of cramps and paralysis. Two or three only were serious, and all recovered. Dr. Jaminet asserts that none of these men had been examined by him, having been employed before he gave his special attention to the West Pier.

A boy had been smuggled in by a friend, and was taken sick the first day. The next day the doctor sent him home, with the injunction not to return; but he came back two days after, and entered the caisson again. After the first watch he was attacked again, and did not recover for a month. On each occasion he was insensible when carried to the hospital. He was twenty years old, and very slightly built.

The air pumped into the caisson was of course very much heated by the work of compression, and the cylinders of the air-pumps and the pipes were kept covered with water as much as possible, in order to keep the temperature down. For some reason, perhaps the temperature of the external air, the air in the

* This man was very sick for three months, and for a long time suffered partial paralysis; and though now (1881) in fair health, he is still lame, and in some of his organs he still feels the effects of his paralysis. For years he had little or no muscular control of the sphincters of the rectum and bladder. At last accounts, however, he was greatly improved, and considered himself nearly well. His joints are unusually sensitive to changes of temperature and barometric pressure.

caisson of the West Pier during two days in April was warmer by some 16° than usual. A corresponding increase of course took place in the temperature within the air-lock, where the thermometer reached as high as 90°.

The doctor was greatly concerned about the effect of this temperature, and in order to keep it down he had an ice-box placed over the supply-pipe.

Notwithstanding the doctor's vigilance and care, cases of cramps and paralysis were of almost daily occurrence. Satisfactory results were obtained only when the following rules were rigidly enforced: 1. The watches were reduced to one hour each, three in number, alternating with long rests of three hours. 2. The men were kept at the pier all day; were required to bring their dinner, and whenever absent for a day they were re-examined before returning to the air-chamber. 3. The men were required to lie down and keep quiet for at least thirty minutes after each watch. Some hot beef-tea was given to each man at dinner.

No new cases occurred for ten days. Meanwhile the submarine work of the West Pier was finished.

On the 11th of May, work was resumed at the East Pier. Men worked three watches of one hour each, distributed over twelve hours. Pressure, 49 pounds. On the first day there was one case, which resulted in speedy death. The victim had worked three months at the other pier, and had suffered no inconvenience. He was on duty from 8 till 9 o'clock, and felt well after coming up. As he had neglected to bring his dinner, he was allowed to go ashore at 11.30 to get a meal. He, however, got nothing to eat, but drank in a saloon. He returned just before 1 o'clock, and worked from 1 till 2. On leaving the air-chamber he, in common with the rest of his gang, came through the air-lock in "*less* than four minutes." He was taken sick in the air-lock, and was unable to climb the stairs. He became unconscious while being brought up, and died two hours afterwards. The *post-mortem* examination showed that he had had no dinner, and only a light breakfast.

It appears that the temperature in the air-chamber was unusually high. The external air was 66°, and as no adequate cooling-apparatus was in use, the air from the pumps must have entered the caisson very much heated. On the following day, by noon, the air-supply came through a coil of 150 feet of copper pipe immersed in the river. The temperature in the air-chamber fell to between 60° and 70°.

The doctor at once transferred the ice-box to the air-lock, and enforced his rules strictly. Fourteen cases occurred between the 11th and 27th, when the filling was completed. Only one was serious. This patient had not only paralysis of the legs, but fever and hemorrhage of the lungs. He had evidently been unfit for the work. He recovered in two weeks.

During the last few days there was room for only three or four men to work at once, and they changed gangs every half hour. Moreover, the doctor was present and examined every man once in six hours.

In spite of the efforts to keep down the temperature, the men complained of the heat, and of being very tired on coming out, and not infrequently of having headache. As soon as a man complained of pain or numbness, he was required to rest over one watch.

To prevent the men reckless of danger from passing through the air-lock too rapidly, the size of the inlet and discharge-pipes was changed, so that though the valve was *wide open*, the stipulated time could not be curtailed. One can imagine the imprecations bestowed on the "slow coach" by men in haste to get out.

SUMMARY OF CASES REPORTED FROM THE EAST AND WEST PIERS.

	Cases.
At the City Hospital, reported by Dr. E. A. Clark	35
Reported by Dr. Paul F. Eve (other hospitals and elsewhere)	3
Reported by Dr. A. Jaminet	49
Not reported by physicians	4
Total	91
Number of serious cases	30
Number crippled for life (apparently)	2
Number of deaths*	13

The whole number of men who worked in the air-chamber of the East Pier was three hundred and fifty-two. This num-

* One of the men did not die till the following year, but as he remained all the while a helpless paralytic, his death is properly attributed to the air-chamber influence.

ber includes many of those who worked at the West Pier, but many, probably one hundred and fifty others, who worked only at the West Pier, are not included. The ninety-one cases given above include only the deaths of those requiring medical treatment. There were probably a full hundred others slightly attacked, eliciting a few groans, but more jokes.

In his report of October, 1870, Mr. Eads gives the names of forty-eight men "who were employed in the caisson of the East Pier from the time it entered the bed of the river until it was filled with concrete."

EXPERIENCE OF THE MEN AT THE EAST ABUTMENT.

Three important changes had been made in the East Abutment, intended to subserve the comfort and health of the men: First. The air-locks were 8 feet in diameter instead of 6. Second. The candles lighting the air-chamber burned in globes which discharged the products of combustion into the open air. Third. An elevator in the central shaft was used to bring up the men at the expiration of their watches.

The first change arose from a desire to give the men more air to breathe while waiting in the lock. The second contributed certainly to the comfort and cleanliness of the men, and hence to their health. The elevator seemed indispensable, and justified itself a thousand-fold. The winding stairs numbered one hundred and ninety steps. What a torture to weary "submarines!" The eminent French engineer, Malezieux, after visiting St. Louis to see the work in progress, spoke enthusiastically of this improvement.*

The success of the regulations finally adopted at the channel piers on the suggestion of Dr. Jaminet led the chief engineer to place him in charge of all sanitary measures at the East Abutment. He entered on his duties when the caisson was 56 feet below the surface of the river; pressure, 27 pounds (above the normal). He found seventy-six men at work in the air-chamber. They were in four gangs: two by day and two by night, working six hours each: two hours on and two off. *All of them had worked in the air-chambers of the East or West Piers.*

During the month the number of men was increased to one hundred and forty. Of one hundred and thirty-three applicants examined, sixty-seven were rejected as unfit for the work. The most common cause was "general debility, caused by intemperance." No men were received older than forty-five years.

A building with berths, mattresses and blankets, and an hospital, were provided. The men were required to lunch at the abutment. Beef-tea was furnished to every man at his meal. No one was allowed to leave the works till one hour after his work for the day (or night) was over. The men were examined daily, and no one was permitted to enter the air-chamber unless in good working condition.

When the pressure reached 32 pounds, a day's work was reduced to two watches of two hours each, with rests of four hours between them, and perfect rest lying down for one hour after the second watch. The doctor had two slight cases of paralysis, but in each case the patient recovered in twelve hours so as to go home alone.

When the pressure reached 34½ pounds, the work was reduced to three watches of one hour each, with intervals of rest three hours long. Two men were taken sick, who recovered in twelve hours.

When the pressure was 40 pounds, the elevator was stopped for about twenty-four hours (in consequence of a leak in the wall of the main shaft), and the men had to climb one hundred and seventy steps after each watch. Four men were taken sick with pains and paralysis about twenty-five minutes after coming up the stairs. They all recovered in about twelve hours. After the elevator came in use again, no case occurred for four days, when, the pressure being 42½ pounds, six men were taken, though within twelve hours all were discharged from the hospital. The doctor asserts that the men fell sick partly through their not resting as ordered. On reaching a depth of 100 feet, by order of Mr. Eads, a day's labor of the air-chamber

* "What an advantage not to have to waste the time needed for descending and climbing a height equivalent to ten stories of a Parisian house! What relief to the men, generally exhausted at the end of their task! What convenience for the transmission of orders, for the introduction of tools, for communications of all sorts."—[*Annales des Ponts et Chaussees*, 1874, *p.* 349.]

men was reduced to two watches of forty-five minutes each. No more cases of sickness for ten days.

During the next ten days the air-chamber was full of water, in consequence of the tornado of March 8, 1871.

Two cases happened on the 18th, while the elevator was still out of repair. Both cases were light. Pressure, 46 pounds.

The comparative immunity enjoyed thus far at the abutment seems to have made the men reckless, and the doctor complains that they would not obey orders as to lying down after coming from the air-chamber, and as to not drinking water for thirty minutes after coming up. (No reason is given for the rule last referred to.)

One man worked two hours instead of forty-five minutes, and then did not lie down on coming out. He was taken in the usual way. Some half-dozen light cases, easily disposed of, occurred previously to April 14, when the pressure was 49 pounds. On that day a man was taken, who died two weeks later. This was the *only death* by compressed air at the East Abutment; and it would appear from the report of the doctor and of Superintendent McComas that the man brought his fate upon himself. He had failed to bring his dinner, so went home to eat it, contrary to orders. Then, on his way back, he "filled himself" with beer. Moreover, on coming up from his second watch, he left the works before his hour of rest was up. These facts were duly recorded by the superintendent on the day of their occurrence. On reaching home in the afternoon, the man was taken sick with vomiting. His dinner had evidently been eaten with great haste, and was still undigested. In a few minutes general paralysis supervened. The history of his case up to his death shows that the man's blood was in a bad state. He had worked in the air chamber over three months.

Two slight cases close the list; one was that of a man who walked up the stairs instead of taking the elevator, and was taken sick on reaching the top.

SUMMARY OF CASES AT THE EAST ABUTMENT.

Number of cases	28
Died	1
Completely recovered	27

Of all those that died from the effect of compressed air, eight were examined *post mortem*. In all cases the brain and spinal cord were congested. As a rule, the interior organs of the body were excessively congested. There was no doubt that the immediate cause of death lay in the influence to which the men had been exposed in connection with their work in compressed air, though in nearly every instance the *post mortem* revealed weaknesses and susceptibilities, which, could they have been known earlier, would have caused the rejection of the men by the medical examiner. When death did not intervene for some weeks, the developments were much confused. Four of the reports are given below, in the belief that the importance of giving full information justifies their insertion.

Theodore Louis Baum was a German, twenty-one years old. He was admitted to the hospital March 22d, 1870; he died the next day. The coroner reported:

"On examining the contents of the cranium, the substance of the brain was found overcharged with blood, oozing freely from minute points on section. The meninges were also highly congested, and considerable serous effusion between them, most marked under the arachnoid. The spinal canal was also opened and examined, and about the some condition existed here as in the brain. The effusion under the dura mater was well marked. There was also found in the inside of the dura mater, at several points, small clots of extravasated blood. In examining the thorax, the small capillaries of the pleura and pericardium were found highly injected. The lungs were highly congested, but much less than the other organs. All the abdominal viscera were entirely congested; clots of extravasated blood were found in the kidneys, and small dark patches on the mucus membrane of the bladder, resembling ecchymosis."

John Sayers, twenty-two years old, was admitted to the hospital after his first watch of two hours. He died in twelve days. The coroner reported as follows:

"The brain and spinal cord were found highly conjested, the latter being softened in many places to pulpy consistency. There was evident subarachnoid effusion, and probably more than a normal quantity of fluid in the dura mater of the cord. Small clots of extravasated

blood were found at different points on the external surface of the latter membrane. All the abdominal viscera were surcharged with blood, the lungs suffering less in this respect than any of the other organs. There were clots of blood found in both kidneys; one of the ureters was very much enlarged."

Henry Krausman, age twenty-seven years, a German, was taken sick March 21. He died in the hospital two days afterward. The *post mortem* was recorded as follows:

"The whole contents of the cranium were found highly congested, with effusion beneath the arachnoid, the vessels of the latter membrane being highly injected. Blood oozed freely from the substance of the brain on section. The spinal cord presented pathological conditions precisely like those of the brain, with the addition of the existence of clots of extravasated blood at different points inside the dura mater; there was also a congested condition of the thoracic content, less marked probably in the lungs than in the other organs. The abdominal viscera were very highly congested, with extravasation of blood in the kidneys. The mucous membrane of the bladder was healthy, and a small quantity of bloody urine was in the bladder."

William Sayler was a German, thirty years old, of medium stature, and well built. He worked three months at the West Pier, where the pressure was for two weeks 40 pounds to the square inch, from which he suffered no inconvenience.

On May 11 he began work at the East Pier, where the pressure was 49 lbs. above the atmosphere. He worked from 8 to 9 o'clock A. M., and felt well after coming up. He went ashore at 11:30. At 1 P. M. he resumed work, and finished his watch without complaint. While in the air lock, at 2 o'clock, he felt sick, and was unable to ascend the stairs. He became insensible while being carried to the hospital, where he remained insensible till 4:20 P. M., when he died.

A *post mortem* examination was held, sixteen hours after death, by Dr. Jaminet, which elicited the following facts:

"*Cranium.*—All the blood-vessels of the scalp, as also all the membranes covering the brain, were highly congested, and about two ounces of serum escaped from the vertebral canal when the brain was removed. The brain was congested and two ounces of serum found in the ventricles.

The heart was of normal size; the right ventricle, as also the left, were normal. The lungs were inflated and of normal appearance, but there were large *adherences* around the base of the right, which seemed to be of long standing. The liver was normal as well as the spleen. The kidneys were normal, as was also the bladder, but empty. The stomach normal *and entirely empty; no traces of food were found*, which confirmed my opinion that this man had not taken any dinner, and probably a very light breakfast, but had been drinking beer and whiskey quite freely, as it was afterwards ascertained."

GRAND SUMMARY.

Total number of men engaged in the air chambers of the East and West Piers and East Abutment, about	600
Cases reported by Dr. Clark	35
Cases reported by Dr. Eve	3
Cases reported by Dr. Jaminet	77
Cases not reported	4
Total	119
Number of deaths	14
Number of *post mortem* examinations	8
Number known to be crippled	2

A majority of all cases, including at least three-fourths of those that died, worked in the air chamber only *one day*, and generally but *a single watch of two hours*.

Two-thirds of those taken sick at the East Pier were attacked immediately on coming out, either on the stairs or as soon as the top was reached. In other cases the men were generally attacked within half an hour.

At the East Abutment, with the exception of the man who died, as already detailed, there were no serious cases. Of these twenty-eight cases were—

Attacked immediately after leaving the air lock	4
Attacked 15 minutes after leaving the air lock	4
Attacked 20 minutes after leaving the air lock	12
Attacked 25 minutes after leaving the air lock	2
Attacked 30 minutes after leaving the air lock	6
Attacked later than 30 minutes after leaving air lock	0
Total	28

I have now given a statement of facts and personal observations sufficiently full for an intelligent discussion of the whole matter. I frequently visited the air chamber of the East Pier, but my visits were short, and I felt no special inconvenience. Neither Mr. Eads nor his assistants, nor even the superintendent, though almost daily in the air chamber, can add much to our stock of information. None of them suffered beyond an occasional numbness, or a slight pain in the joints. As a rule, chance visitors had no personal sufferings to report beyond a "frightful pain" in their ears while making the first passage of the air lock. I have no record that any of the ladies who visited the air chambers ever suffered at all. Sometimes they bravely made the passage of the air lock while the gentlemen attending them were forced to withdraw.

I now propose to discuss at some length these very important facts, giving first the views of others expressed at the time, and finally, the conclusions to which I have been led by a very careful examination of all points.

The "Bridge cases" excited great interest and discussion in medical and scientific circles, but the physicians were not at all agreed as to the manner in which the compressed air acted so as to produce the symptoms exhibited.

Dr. E. A. Clark, physician at the City Hospital, believed that the increased atmospheric pressure upon the surface of the body compressed the superficial vessels and forced the blood in upon the interior organs of the body, causing the congestion observed. The lungs, having an internal equalizing pressure, were consequently least affected.

Another eminent physician thought that the men were poisoned by carbonic acid, which had been abnormally retained within the system while in the air chamber, but which was set free as soon as the pressure was removed.

Dr. Jaminet, the physician in the em ploy of the Bridge Company, thought that the men were sick from physical exhaustion, caused mainly by the rapid waste of the system, which, in his opinion, went on four times as fast under a pressure of four atmospheres as when under the normal pressure. Exhaustion was hastened also by labor in the air chamber, and the effort of climbing a long flight of stairs on coming out. He refers, in support of his theory, to the following well established facts: That in the air chamber, under four atmospheres, four times the usual amount of oxygen was inhaled at each inspiration; that the breathing was more rapid; that the men sweat profusely all the time they were in the air chamber; that the amount of urine secreted was larger than usual, and of greater specific gravity; that men whose vital energies were at a low ebb, and men with empty stomachs, were struck down first; that the muscular effort of walking up stairs increased the chances of sickness; and that long watches were more dangerous than short ones.

Dr. Jaminet's argument is founded on strong premises. If he does not reach the whole truth, he does a part of it. Certainly he was led to the adoption of measures, some of which worked admirably and went far to confirm his conclusions.

It is not so much my purpose to show that the views of others are wrong or inadequate, as to present an explanation which, so far as I know, is entirely new. While I award to Dr. Jaminet great credit for his professional zeal and considerable success in his efforts to account for and guard against the evils noticed, I insist that the theory of ordinary physical exhaustion fails to account for the phenomena observed.

My opinion is that *the vital energies of the men taken sick were to a great extent paralyzed by loss of heat.* This loss was due—

1. To the expansion of the air in the lock, while coming out.
2. To the expansion of the free gases and vapors within the body, when relieved of the abnormal pressure.
3. To the liberation of the gases held in solution by the liquids of the body.
4. To the severe physical effort of climbing the stairs.

I think that the chief loss of heat was suffered in the air lock when coming out of the air chamber, but that the loss continued, though more slowly, during the succeeding few minutes, while the men were ascending the stairs and the liberation of gases was going on.

The great loss of heat which necessa-

rily attended every exit from the chamber, though incidentally noticed, seems not to have received proper consideration. A few words are necessary to show the importance of considering this point carefully.

The central air lock of the East Pier contained about two hundred cubic feet. It would hold thus ten men and 175 cubic feet of air. One hundred and seventy-five cubic feet of air under a pressure of four atmospheres would occupy, under the normal pressure of one atmosphere, seven hundred cubic feet, the temperature remaining the same. Now the loss of heat resulting from the expansion of this air, as a part of it is allowed to escape, is easily found by the rules of thermodynamics. Air at 70° expanding against a pressure diminishing from four atmospheres to one, *without receiving heat from surrounding objects*, is reduced in *temperature to 166° below zero!*

It was noticed that the escape cock was often covered with frost, and that the temperature, as indicated by a thermometer in the air lock, sometimes fell to 32°.* It probably fell very much below that point, but the thermometer was hung against the iron wall of the lock, from which it was all the while receiving heat, both by conduction and radiation, and it did not represent the temperature of the air in the center of the lock. Air at this low temperature extracted heat from the bodies of the men at a very rapid rate. From this cause alone a man would come out of the lock exceedingly cold. *This* loss of heat could be somewhat guarded against by the use of flannels, overcoats, and blankets.

But the absorption of heat through expansion takes place *within* the human body as well as *without* it. All the liquids of the body are surrounded by a certain amount of their own vapor; and gases, such as air, carbonic acid, etc., exist in cavities and pores all through the body, notably in the abdomen. Just how much this gaseous volume is, it is impossible to tell; but there can be no doubt that it exists in considerable quantities, and that gases pass by insensible degrees through all animal tissues. Now, in coming from a pressure of four atmospheres, there would be four times the normal amount of such gases in one's body. In passing through the air lock, three-fourths of this must imperceptibly escape by expansion, and during the expansion they must absorb and carry off heat from the interior of every organ of the body. Where the gases were most abundant, the loss of heat would be the greatest, viz., in the abdomen.

Very closely connected with this was the loss of internal heat through evaporation and the liberation of gases. *The amount of gas which a liquid can hold in solution is proportional to the pressure.* All the liquids of the body probably contain air and various gases in solution. After an hour's stay in an air chamber under a pressure of four atmospheres, the amount of gases held in solution in the liquids of the body was probably very nearly four times the normal amount. The absorption of the gases was attended by the evolution of heat and a feeling of exhilaration This feeling every visitor noticed on entering the air chamber. Now, on return to the air lock, and to a reduced pressure, this extra amount of gas began to escape, and one felt the effect of processes just the reverse of those previously experienced. The evaporation was attended by a loss of heat and a depression of the spirits. The increased vital energy gave place to a very low ebb of vitality and an all-pervading sense of frigid helplessness. It will be remembered that Faraday produced the most intense cold—*166° below zero*—by allowing very volatile substances to *evaporate* under a greatly diminished pressure.

These losses of heat can be considered only qualitatively; quantitative results are hard to reach, but an admirable and perfectly analogous experiment could easily have been tried, illustrating the heat absorbed by evaporation. Had Dr. Jaminet, after boiling water in the air chamber, taken a gallon of the water, every atom of which had a temperature of 297°, into the air lock with him, on his return to the upper air he would have found, when he came out of the lock, no matter how quick his passage, that the water remaining in his pail had a temperature of exactly 212°, and that considerable of the water had evidently *boiled away* in the lock. This experi-

* It should be remarked that the condensation of watery vapor into dew and frost around the escape-pipe slightly mollified the extreme cold by giving up its latent heat of evaporation.

ment was not tried, but every physicist knows that I am right in my statement of the result.

Now, how can we account for the loss of 85° of heat in the water? The answer is easy: A part of the water formerly confined by the pressure of four atmospheres has escaped from under a less restraint, and, while transforming itself into a gas, has robbed the water remaining of a portion of its heat. Any liquid saturated with any gas would, under a diminished pressure, part with its heat in precisely the same manner.

It is obvious that the liberation of gases held in solution by the fluids of the human body is a dangerous process. In escaping from the corpuscles of every liquid, and from within every tube and duct, there are two possibilities: First, the escape may be so rapid and violent as to rupture the minute tissues; and, secondly, the absorption of heat may be so great that the vital fluids may lose their vitality.

There is another point: The escape of gases held in solution by increased pressure is not instantaneous when the pressure is reduced; it requires time, even if the pressure is suddenly removed. Hence the internal loss of heat did not end with the exit from the air lock; it went on for some minutes, during which the vitality of the system was being reduced to a minimum.

There was yet one more demand made upon the vital heat and energy of the air-chamber men when they emerged, half frozen, from the air lock of the East Pier, namely: the mechanical effort of climbing 110 feet vertically before physical reaction had had time to set in, and while the loss of heat from evaporation and the liberation of gas was still going on. This effort alone, as has been found by experiments, reduces the temperature of the body. To raise 150 pounds 110 feet is equivalent to raising the temperature of one pound of water 22°. Hence twenty-two thermal units would be lost in the ascent by every man.

When we consider the combined effect of the four causes of loss of internal heat and vitality, taken in connection with the necessarily exhausted condition of men who had been laboring hard, secreting excessively, and sweating profusely, we cannot be surprised that they were chilled to their vitals, and that many of them failed to pass the minimum point without cramps and paralysis; we are rather surprised that so many escaped. We know that the temperature of the vital organs varies between very narrow limits. We know that sudden cold (as in the case of a man swimming in cold water) produces cramps in the legs, and sometimes intense headache. The almost invariable symptom in the Bridge cases was the paralysis of the bladder and the sphincter ani., both caused doubtless by loss of internal heat.

This brings me to the consideration of a very suggestive remark of Dr. Jaminet. Feeling, most certainly, that his theory of exhaustion did not fully account for the symptoms, he adds, with less regard for his theory than for a truthful statement of facts as he observed them: "The paresis [weakness] or paralysis is but the result of reflex action caused by *the spontaneous refrigeration of the whole system, but principally of all the abdominal organs.*" No more satisfactory confirmation of the truth of the explanation I have given could be asked than this observation of Dr. Jaminet.

One remark in reference to the time when the men were attacked. None were ever attacked on entering the caisson; none were ever sick when in the air-chamber, no matter how long the watch. In one or two cases the men felt sick just before leaving the air-lock. At the East Pier, two-thirds of the men were sick by the time they reached the top of the pier: the other third was attacked a few minutes later. At the East Abutment, twenty-four out of the twenty-eight taken sick were not attacked till from fifteen to thirty minutes after leaving the lock, and *none after the lapse of half an hour.* It is evident that about half an hour was necessary to reach the minimum point of vital heat; at that point the system began to recover. It is quite obvious that men exhausted by hard work, by insufficient food, or by dissipation, would be struck down early in the contest between vital strength and the inflexible laws of thermodynamics.

One word as to the pressure upon nerves, blood-vessels, and the brain. In nearly every *post mortem* examination, an increased amount of serum was found in the vertebral canal or within the cavity

of the skull. I may not be physiologist enough to explain why this was the case, but I do not feel, as many do, that it furnishes a satisfactory explanation of the phenomena of sickness and death. It would appear that some yielded suddenly, and died in a few minutes; others were so prostrated, their energies were so far overcome and destroyed, that restoration was impossible, though sufficient vitality remained to prolong life for a few weeks; with others the struggle was long and severe, and the battle finally drawn, leaving the unfortunate victims with certain organs permanently impaired.

It must not be forgotten that *no one was attacked while under pressure*, nor while pressure was being applied; the fatal moment was when the pressure was removed, or within half an hour from leaving the air-chamber. Now, there can be no doubt but that the aerostatic and hydrostatic pressure throughout every part of the human body corresponded closely to the external pressure. In so far as there were cavities in the skull and spine containing gas and air, compression took place and additional air or liquid was forced into them. The internal pressure was sensibly equal to the external; any momentary difference produced acute pain, and no tissue was strong enough to withstand any great inequality. The pressure upon the spinal cord, upon the blood-vessels and the brain, *applied alike to every man, whether he fell sick on coming out or not.* If serum, or blood, or air was forced into a cavity, it was generallv absorbed, or returned without injury. A too rapid change of pressure would, of course (neglecting any question of heat), tend to cause head-ache, and do harm in the sockets of the joints.

As to the waste of the system while in the air-chamber, I think that Dr. Jaminet has greatly overrated it. Unquestionably, the waste was abnormally rapid. Men took twenty-one full inspirations per minute, instead of eighteen. It is true, a man inhaled four times as much oxygen as usual at a breath; but so he did of nitrogen, and, as usual, the amount of oxygen consumed was largely regulated by the amount of nitrogen mixed with it. Candles burned about sixty-seven per cent. faster under four atmospheres than under one. It is possible that the vital processes in the human body were accelerated in about the same ratio. Exact information as to the rate of waste and the influences of long watches is wanting. It is to be regretted that some one did not think to try experiments upon animals. Dogs, well fed, would doubtless have lived some days in the air-chamber, and, if carefully brought out, might have survived unharmed.

In conclusion, I agree with Dr. Jaminet, that only sound men should be employed: that they should not be exhausted by long terms of labor; that they should be well fed; that they should not pass in or out too rapidly: that they should, on coming out, be spared immediate hard work. For some unaccountable reason, Dr. Jaminet allowed twice as much time for entering the air-chamber as for coming out, though he saw that the coming out was the critical thing. His rule should be reversed: say eight minutes for going in and twelve for coming out, the pressure being 48 pounds above the normal.

But I would add to the above requirements one other, and *the most important of all*, namely: that *such a supply of heat should be given every man that he could lose a large amount and still have plenty left.* This could readily be done in various ways.

My conclusions may be stated in the form of—

RULES FOR THE MANAGEMENT OF MEN AT WORK IN COMPRESSED AIR.

1. Men must be sound and well fed. They should eat a hearty meal about one hour before entering the air-chamber.

2. The periods of labor should be diminished as the pressure increases: say, to two watches of two hours each per day under a total pressure of four atmospheres.

3. Men should have perfect rest and warmth for half an hour after coming out. This includes the use of an elevator.

4. The pressure in the air-lock should not be increased more than six pounds per minute, nor diminished more than four pounds per minute. If, when the pressure is increasing, any one has pains in his ears which cannot be removed by blowing his nose, or by swallowing

water, the inlet of air should be stopped and the man sent out.

5. Every man, just *before leaving the air-chamber*, should be required to swallow about a pint of hot coffee, tea, or soup.

6. There should be separate air-locks for *entrance* and for *exit*. The *exit* air-lock should be provided with heating apparatus, which should maintain a proper temperature and furnish direct heat to the bodies of the men.

Carefully observing these rules, it is probable that men can safely work under a pressure of five atmospheres.

SANITATION IN ANCIENT ROME.

From "The Builder."

THERE is every probability of Italian art becoming a thing of the past, especially if, as seems to be the case, the deterioration so noticeable on the Tiber should extend itself from one end of the Italian Peninsula to the other. Modern Italian architects and artists appear to be far behind their glorious predecessors, who have made their works serve for imitation to many generations of artists. But modern Italians have also deteriorated, compared with their forefathers, in other domains of what constitutes civilized life. This remark applies especially to the question of sanitation. We know, at least travelers very often do to their cost in the loss of health, that in sanitary matters Italy does not occupy a very high place; and from a lecture recently delivered by Professor Uffelman, of Rostock, it appears that in this respect they are not nearly on the level occupied by the ancient Romans. To do them justice, however, it ought to be added that, for that matter, they are no worse than other nations, who very often are behind their ancestors in a good many things, and might well learn from them. At present however, we have only to deal with Rome; and from the lecture to which we have referred, and which throws much light on a subject hitherto very little known, it appears that in ancient Rome, the metropolis of former times, there existed important institutions for preserving health amongst its inhabitants.

Although there were then at Rome no sanitary inspectors, in our modern sense, the Ædiles and Censors were charged with sanitary functions. It was the Emperor Augustus who first appointed inspectors of water-supply and superintendents of sewers, who exercised a sort of police supervision also over the river of the city, the Tiber. The city of Rome was early provided with a system of sewers, which at first, at the time of King Tarquinius Priscus, only had the object of draining some parts (amongst them the Forum) of the city, but which later likewise served the purpose of modern sewers, that of receiving and carrying away all descriptions of refuse. Under Tarquinius Superbus this system of sewerage was completed by the construction of the Cloaca Maxima (the largest sewer), leading to the Tiber, which still exists; and, whatever be the difference of opinion as to the provision of large sewers, may well rank with the best sewers of our time, so far as regards excellence of construction. For five centuries this system of sewerage was carefully preserved, extended, repaired, and cleaned. But with the decline of the city this great work was permitted to fall in ruins, and only the principal sewer remained, which has been preserved down to our day, but choked up by mud, and at its end toward the Tiber filled up to two-thirds its height.

The second fundamental condition for the preservation of the public health, that of providing the city with an abundant supply of good water, was done full justice to in ancient Rome. When the water in the Tiber, in consequence of its contamination by the population inhabiting its banks, could no longer be used for drinking, the Censor Appius Claudius constructed an aqueduct, for the greater part underground, from Praeneste to Rome, which was called after him the Aqua Appia. Fifty years later this was supplemented by a second; and, after other seventy years (144 B. C), by a

third aqueduct, the Aqua Marcia. The latter brought the water from the Sabine Mountains, was thirty-two miles long, and supplied excellent water, which for centuries refreshed thirsty Romans, and which was originally constructed at a cost of £2,000,000, an enormous sum at that time. It was in ruins for many years, but was restored ten years ago, and has since then furnished Rome with its water supply. Numerous other aqueducts, some of them very magnificent and gigantic, were built. Toward the close of the Empire, nineteen aqueducts, fourteen larger and five smaller ones, conducted the water to the metropolis. At the end of the first century after Christ, ten aqueducts supplied a daily quantity of 33,000,000 imperial gallons of water to Rome. As four-eighths of this volume were used by the Thermæ, or public baths, and one-eighth by the imperial palaces, there remained yet three-eighths for the use of private consumers, the quantity supplied to the two million inhabitants of the metropolis being sixty-two imperial gallons of water per head per day for domestic use. The water was conducted through the city in leaden or earthenware pipes. The aqueducts were fully protected by law. No buildings could be erected over them, no trees planted near them. Heavy punishment was inflicted on persons polluting the water or damaging the aqueducts or conduits. With the decline of Rome, those splendid institutions also fell into ruins; but they were partly destroyed by hostile armies or besieging forces, in order to compel the Romans to surrender their city.

Public baths reached a state of perfection in Rome such as has not been attained by any other nation. At first, of course, only the Tiber formed a natural basin for ablutions; later artificial public baths were constructed, and under the emperors the Thermæ were introduced. Those magnificent bathing establishments not only furnished cold, warm, and hot baths, but they supplied also shampooing baths and cold ablutions; anointment of the body was likewise practiced there. Those institutions still serve in many cases as patterns for baths erected now for our well-to-do classes, but which at that time existed in incredibly large numbers, the use of them being, besides, free to all comers. But those establishments did not bring with them the unmitigated advantages it was probably at first thought they would furnish; they degenerated, and became the abodes of idleness and hotbeds of vice.

There was no want of regulations in ancient Rome as to height of houses and width of streets. When, after the great fire, under Nero, the city had to be rebuilt, regulations of this description had to be strictly followed. There was likewise an abundance of public places of amusement, walks, and public gardens. The Government also looked to the supply of provisions, its solicitude at first being merely confined to taking care that a sufficient quantity of corn was continually stored in Rome. Many descriptions of food—for instance, meat—were also inspected. Of the stored grain, large quantities were given away to the poor since the time of Cæsar; during the reign of Pompey very nearly £1,000,000 was spent for this purpose annually.

There existed many charitable institutions, although there were few of them according to our notions. The Emperor Nerva sank large funds, the interest of which was appplied in supporting the children of poor parents and orphans. Trajan placed nearly 5,000 children on the list of recipients of corn. Antonius Pius founded an institution for poor girls. Hospitals did not exist very early; they sprang up under the influence of Christianity, their number amounting in the ninth century to over twenty. Nothing was done in the direction of public care for the poor until the middle of the second century after Christ. Antonius Pius appointed communal physicians, who were free from taxes, but who were under the obligation of rendering certain services to the State and the commune, and who had, among other things, to treat gratuitously all the poor of their respective districts. Alexandrus Severus was the first to pay them a salary, and gave them the name of *Archiatri populares*.

The ancient Romans did not permit the industrial classes to poison the air for them. Fullers, who used urine in a state of putrefaction in the manufacture of cloth, had to carry on their calling outside the city gates or in its remote quarters. Roman law-makers had a

watchful eye on the disposal of the dead. At first, deceased persons were interred inside the city; later those interments were prohibited, and a public cemetery was laid out outside its walls. Funeral funds existed very early in Rome, which paid, as in our time, a fixed sum at the death of a member, if the latter had subscribed regularly. Cremation was introduced at the time of the Decemvirs, at first only in the case of individuals, but later, after Sulla, cremation became more common. At one time this was the general mode of disposing of the dead, but committal to the soil was never entirely abandoned, and with the spread of Christianity became again more general. But in the beginning of the second, during the third and fourth, and the beginning of the fifth centuries, the Christians used the subterranean cemeteries, the so-called Catacombs, in which the bodies were placed in hollows cut in the walls of the passages driven through the tufaceous limestone underlying Rome, the cavities being afterwards closed by marble slabs, on which the names of the deceased were engraved. In time these catacombs became more and more complicated.

From the above it will be seen that the institutions and hygienic regulations of the ancient metropolis were very remarkable, and in some respects at least much more perfect than at the present day in many cities and towns, the inhabitants of which think a great deal of their sanitary arrangements.

COMPRESSED AIR, STEAM, OR ELECTRICITY FOR TRAMWAYS.

From "English Mechanic and World of Science."

THE success of the electric tramway in Berlin and Paris, and the proposal that has been recently made to construct an elevated circular railway in the latter city to be worked by electricity, have served to attract renewed attention to the debated question of the best motor for street tramways. It is conceded that for suburban districts steam may be used with impunity, but many objections and much opposition is offered to its introduction into the streets of towns; hence the persistence of the advocates of compressed air motors. At the recent meeting of the Institution of Mechanical Engineers, Mr. Scott Moncrieff read a paper on compressed air motors, in which, while admitting that the steam engine was the cheapest and most efficient motor, he contended that in many cases compressed air engines could be used with advantage and even with economy. The success of the electric motor of Messrs. Siemens, and the fact that the municipal commission of Paris have advised the experiment of an elevated electric railway in that city, introduces another rival, and tramway companies will now find it still more difficult to determine on the motor they will employ instead of horses. Recently on the Walton tramways, near Liverpool, a series of trials with steam engines of different designs has been made in the presence of Major General Hutchinson, of the Board of Trade, so that if it is possible to ascertain the actual expenses on an electric tramway, there ought to be no difficulty in determining which motor, all things considered, is most desirable. It is obvious that, so far as dead weight is concerned, there is little to choose between steam and air motors, for if the former need generators and engines, the latter require reservoirs, which being strong enough to resist high pressures are necessarily heavy. With the electric tramway, on the contrary, the dead weight of the motor is very small comparatively, but it is expensive in first cost, and may be found "heavy on repairs," an item which has yet to be calculated with approximate accuracy. The electric motor compares with the air motor in the fact that both take their power from a fixed steam engine, and it is clear that the first question asked by an engineer will be, what percentage of the power developed by the steam engine is transmitted respectively by the two kinds of motor, for, other things being equal, if

the electric motor is capable of transmitting a greater percentage of useful effect, the air motor is out of court. In the case of the steam motor we may assume that a locomotive is as economical as the fixed generator and engine, and as its power is applied direct, it is obvious that it is more economical than either air or electricity; but it possesses disadvantages which do not pertain to its rivals, in the shape of smoke, dust, exhaust steam, heat, and liability to explosion—though as far as the last is concerned, it is impossible to conceive that there is not some risk of rupture in the case of reservoirs containing air at pressures of 1000 lbs. and upwards. In the paper above mentioned Mr. Scott-Moncrieff gave a number of technical details of the construction of his motor, and of the arrangement of the valves, etc., by means of which the highest possible duty was obtained from the compressed air. The car to which it is attached travels seven miles with one charge of air, the maximum pressure of which is twenty-six atmospheres—say, 400 lbs. The car carries forty passengers, and makes about twenty-five stoppages, and the cost of fuel, on the "large scale," is one halfpenny per mile, coal costing 10s. per ton. Mr. Scott-Moncrieff contends that the insignificant saving effected by heating the air before passing it into the cylinders is not worth having on such a route, and relies for the efficiency of his motor, which is perhaps the best of its kind, on careful regulation of the rate of expansion, which is effected automatically, but requires alteration when the pressure falls or rises beyond certain limits. On p. 2, last volume, we gave a short account of the Mekarski air locomotive, which had been used for some time on the tramways in Nantes; but little or nothing has been done with it in London, where, however, Col. Beaumont's motor is now at work between Stratford and Leytonstone. This latter motor, which we described some time ago, has an initial pressure of 1000 lbs. in the reservoir, and, at one time, was thought so highly of that it was subjected to a series of trials on the Metropolitan Railway. In the course of the discussion on Mr. Scott-Moncrieff's paper, however, Mr. Tomlinson, jun., engineer to the railway, said he had made an estimate as to the cost of supplying compressed air for the engines that ran out of Aldgate alone, and he found that twenty-six large Cornish boilers would be required to work night and day, and these, with the engines, machinery, and other plant, would occupy about five acres of land, and would cost more than the whole of the locomotives at present on the line and their working expenses for a long time. The fuel cost of train haulage on the Metropolitan is, according to Mr. Tomlinson, 1½d. per mile for a train of 150 tons weight, with coals at London prices, whereas Mr. Scott-Moncrieff's car, weighing about 7½ tons, and carrying only forty passengers, costs, for coal at Glasgow prices, ¼d. per mile. The weak point of the air-propelled engine is, apart from financial considerations, its want of range of power, for if from any circumstance it is brought to a standstill for lack of power, there it must stick, whereas a steam motor, by getting up pressure, could overcome the difficulty and proceed on its journey. The dead weight of steam and air motors is not altogether a disadvantage, for it gives adhesion; but the chief difficulty in introducing steam engines is the state of the tramways, which, as a rule, are not capable of withstanding the wear and tear of such loads. In the experiments above referred to, made recently on the Walton tramways, three detached steam motors and one combined engine and car were tried. The first was a detached motor, made by Messrs. Hawthorne, of Newcastle, and completely enclosed in a light ornamental case about the height of an ordinary tramcar. This machine worked easily, without noise, emitted steam only now and then, and quite suppressed smoke, while the brakes acted quickly and effectively. Similar results were obtained with a detached motor made by Duncan and Wilson, of Liverpool, except that there was a little noise. Of the detached engines, that which attracted most notice was Mathew's patent, which has a patent locomotive boiler, and the motion work of which is of steel, including the wheels and axles. This engine drives from either end, and is worked by one man, the whole of the driving parts being placed outside the frames and carefully shut in with casing to exclude dust. The combined engine and car tried was Apsey's patent, made by

Ormerod, Grierson and Co., of Manchester. In this device the boiler is carried at one end, the engines being in the center and beneath the floor of the car; but the arrangements are such that the driver can stand at either end. A light awning protects the outside passengers from any vapors or dust that may escape from the chimney. The weight is in this case all used for adhesion, and the car is stated to have run with greater smoothness and less noise than an ordinary horse car. All these steam motors are well within control, possessing sufficient brake-power to stop them within their own lengths from the maximum speed allowed on tramways; they are practically free from escapes of steam and smoke, and, in short, are well adapted for the work for which they were designed. Steam motors have been in use on some of the tramways of Paris with success; but a variety of considerations have just now attracted the attention of the Parisians to electricity as a means of working their "metropolitan railway." The Parisians, it seems, do not favor the idea of an underground line, which, moreover, could be made only at great expense and at considerable risk to property immediately in the neighborhood of the tunnel; but the streets are now so crowded that some inexpensive method of getting from one part of the city to another is becoming more and more necessary. Tramways have been laid along nearly every possible route, but on some of the principal main lines of traffic they cannot be laid for want of space. The Siemens electric tramway has, however, been favorably reported on by a Committee of the Municipal Council, and is approved by the Parisians; while a French engineer has exhibited a complete scheme for an elevated railway to be worked by electricity, so that M. Chretien's idea is not unlikely to be carried out. The great objection to an elevated railway is its appearance, which will necessarily tend to the disfigurement of the streets and roads through which it passes. On this point it is suggested that the viaduct need not be an ugly mixture of pillars and girders, but may be made ornamental in finish, while it would occupy only a small portion of the wide boulevards through which it would run. M. Chretien's plan is so far complete that it consists of a network of lines with stations at intervals of about 400 meters, so arranged that would-be travelers standing in the heart of Paris would not be more than about 200 meters from a station. The proposed width of guage is about $1\frac{1}{4}$ meter, which would involve a total width of $4\frac{1}{2}$ meters—say 15 ft. The two lines would be carried on girders and pillars, and would be separated by a deep lattice girder in the center. The columns would be 130 ft. to 160 ft. apart, and, the line being floored throughout, would form a shelter from the rain to foot passengers. The vehicles suggested by M. Chretien are 26 ft. long by 5 ft. wide, with doors to open and close automatically at each station. Four places are suggested as suitable sites for locating the engines and dynamo machines, the estimated power of which, for working the line, is set out in detail; but it is obvious that, if electricity is to be installed on such a scale as is implied by a railway, it would be advisable to put down engines and machines capable of also supplying current for lighting purposes in the neighborhood. Estimates of cost and working expenses are of little value at the present stage of the railway; but it may be mentioned that M. Chretien enters at considerable length into the question. For instance, he calculates that the working cost of a line running from the Madeleine to the Bastille would be 40 centimes for each "train," or vehicle, so that four passengers at 10 centimes would pay expenses, and as the car would hold 50, there would be ample room for earning a good profit. The line would be worked on the rapid system; that is, instead of long trains at intervals, single vehicles would call at the stations nearly every two minutes; the fare would be uniform for all distances throughout Paris, and there would be no distinction of classes. Between the two stations above mentioned, is a distance of two and a half miles, and if an electric car can be worked over that length of line for four pence, which is a small fraction more than 40 centimes, there is an important future in store for electric railways. As mentioned above it is probable that an experiment at least will be made, most likely in the Boulevard Voltaire, which is now nearly completed, and if the Parisians are satisfied with that, they will no

doubt put up with the disfigurement of their beautiful boulevards for the sake of the convenience of the railway. In this country it will be simply a question of cost, and if electric railways can be worked economically, they will settle the vexed question of motors for tram lines.

A PROPOSED ASSOCIATION OF WESTERN HIGHWAY BRIDGE BUILDERS.

By J. A. L. WADDELL, C.E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THAT such an organization as the one above mentioned is really needed is apparent to every reasonable man who travels to any extent in the Western country.

Not more than ten or fifteen per cent. of the highway bridges in the West are built upon sound specifications, and of these many are not as strong as they are claimed to be. This is proved by the number of bridge failures of which one reads from time to time in the newspapers, though, if the truth were told, such matters are very often hushed up or the failure is attributed to a washout, a tornado or some other cause which man is supposed to be powerless to resist. It is true that once in a while there does come a hurricane powerful enough to overturn the best of bridges, but such storms are few and far between.

Every bridge should be built so as to resist, without injury to any of its parts, the highest wind pressure observed in heavy gales. As for washouts, they are usually due to the short-sighted policy of the supervisors, to whom is entrusted the responsibility of directing how the bridges are to be built. Rather than make the spans a little longer and raise them a little higher, thus increasing their cost and that of the approaches, they prefer to block up the stream with the foundations and to run the risk of high water reaching the bridge. There is really no excuse for a washout except a gorge of ice or timber, and even this can, in most cases, be avoided. But washouts and tornadoes are not the true causes of most of the bridge failures, for many structures succumb without the assistance of either high wind or high water; they fail simply by reason of faulty design, which makes them unable to withstand the stresses developed in them by passing loads. Worse than this—many of them are scarcely fit to sustain their own weight!

This is a pretty bad state of affairs, and what has been done to ameliorate it? Very little.

About a year ago Professor Vose issued a pamphlet entitled "Bridge Disasters in America; the Cause and the Remedy," which should have done considerable towards raising the standard of American bridges. Unfortunately the work has not met with the reception it deserves, and bridges are built in about the same style as they were before its appearance.

The "remedy" suggested by Prof. Vose is the appointment of State engineers, whose duty it would be to examine before erection the diagrams of stresses and sections of all bridges to be built in their States, and to inspect at least twice a year all the existing bridges.

The pamphlet concludes as follows: "Thirty bridges on an average break down in the United States every year. No system of inspection or control at present existing has been able to detect in advance the defects in these structures, or to prevent the disasters. A system, practical, simple and inexpensive, can be had, which, if properly carried out, will insure in nearly all cases, if not all, the public safety. It lies with the public to say whether or not it will have such a system."

Well, the public, by the indifference it has shown, has clearly indicated that it does not deem such a system necessary; and nothing but a long series of bridge diasters involving great loss of human life will ever awaken it to the fact that something must be done to prevent such accidents.

Now, why cannot the bridge companies themselves undertake the duty that the public refuses to assume?

Every first-class bridge company recognizes the fact that it is to its interest to build good substantial structures, but many of them are forced by the closeness of competition with inferior companies and local bidders to erect bridges that are not approved of by their engineers. They would, probably, very gladly do what they could to improve the bridge business, but are restrained by force of circumstances.

To show how the difficulty may be overcome is the object of this paper.

Let there be formed during the coming winter, when bridge builders and engineers will be comparatively at leisure, an association of all the principal bridge companies of the West, the object of which shall be to *enforce* the building of firm substantial structures.

The word "enforce" is used advisedly, for such an organization would, on account of the standing of its members and the praiseworthy object of its existence, wield great power. It could dictate to county commissioners what quality of bridges they should build, and could prevent the erection of all bridges not up to a certain standard. By taking into the association the manufacturers of bridge material, an arrangement could be made by which local bidders would be unable to obtain iron for doing inferior work. This would soon render the existence of that genus a thing of the past.

By the term local bidder is meant an individual residing in the county where the bridge under consideration is to be built, who has assisted in some capacity or other at the raising of two or three structures, or has been practicing the trade of carpenter or blacksmith, and who, with no knowledge whatsoever of mathematics or the laws of mechanics, gets into his head the insane idea that he can design and build bridges, and proceeds to put that idea into practice. Nearly every county contains at least one specimen of this kind. It is to these men as well as to inferior companies that are due the low standard of American highway bridges, and the numerous diasters which occur every year.

The organization of the association proposed would be a simple matter; the first step to be taken at the meeting of the representatives after choosing a chairman would be the appointing of a committee to draw up a constitution and by-laws, and another, composed of the best engineers, to make out specifications, tables, &c., regulating the style and strength of bridges to be built in future. Sufficient time should be allowed these committees in which to report, as there would undoubtedly be a good deal of discussion before all the various theoretical and technical points could be satisfactorily settled.

The general scheme of the association should be that each company deposit with the treasurer a certain sum of money in cash, say one thosuand dollars, to be held by him as long as the company be represented in the association, as a guarantee that said company will comply with all the rules and regulations of the association. Should at any time the company or any of its authorized agents fail to do so, a standing committee of three to act as judges should decide as to how much of the deposit be forfeited for the offence, and the company should be deprived of all the rights and privileges of membership until such time as the amount forfeited be replaced. In order to insure its speedy replacement, a further fine of so much per month, after the first month, should be added until the deposit be brought up to its original amount.

With the money accumulated from fines, interest on guarantee deposits and, if necessary, annual dues, the association could make many needed experiments upon resistance of bridge materials, and could have the results printed in a publication of its own. Discussions in the papers of the association from time to time would originate new rules, and thus elevate the standard for bridges. But—some one may say—suppose two or three companies refuse to enter the association, will not this be sufficient to prevent its organization? Not at all. Should any company refuse to join the association and continue to build inferior bridges, it would soon be forced either into the association or out of the business.

This statement may sound a little like an infringement of the privilege, that every American has, to do as he pleases, and may seem like coercion of the weak

by the strong, of the few by the many; but such need not be the case. The privilege of membership should not be withheld from any one willing to deposit the guarantee and to comply with the regulations of the association.

Some one may suggest that, if all the bridges in the country be built upon one set of specifications, there would be no chance for improvement by variation in design. By no means; the specifications of the association would limit the *weakness* of bridges, not their *strength*, and any one would be at liberty to make all the improvements he might desire, and ought to be encouraged to do so by the association as a body.

Someone may observe that, if all bridges are to be built upon scientific principles, it will be a little hard upon those who have not received a scientific education. All very true, yet such persons have three courses to chose from: first, to post themselves; second, to employ skilled labor; third, to build after the model of some one who is better instructed. Besides, the tables, &c., of the association would be of great assistance to such persons, enabling them to make good designs with very little calculation.

But then—some one may object—this association would be a monopoly. In one sense perhaps it would, in that it would prevent ignorant men from doing work which ought to be left to those who have spent years in educating themselves for the purpose.

In short, there can be no reasonable objection to the proposed association, and not only would it be a benefit to the bridge companies, but would be also a great boon to the country at large.

THE PRESSURE OF WIND.

From "The Architect."

More than a century ago John Smeaton, the engineer, had a table prepared by his friend, Mr. Rouse, showing the force of wind in pounds to the square foot. It is still reprinted in engineers' pocket-books and other abstracts of science. At one mile per hour the force was said to be .005 lbs., and it ranged to 49.200 to the square foot, which was supposed to represent a hurricane having a velocity of 100 miles an hour. Smeaton said that the evidence for those numbers where the velocity exceeded fifty miles in an hour did not seem of equal authority with those of fifty miles and under. He also explained how the pressure was derived from the velocity, the equation being $P=0.00492V^2$, where P=pressure in pounds avoirdupois, and V=velocity in miles per hour.

According to experiments by Hagen, the pressure of the wind against an inclined rectangular plate is nearly proportional to the square of the velocity, and the cosine of the angle of incidence of the wind. It was also found that the pressure depends to a great extent on the shape as well as the surface of the resisting body. The following table will show the differences between the results obtained by Smeaton and Rouse and those by Hagen:

Velocity of wind.		Pressure in pounds per square feet plane surface.			
			Hagen.		
Miles per hour.	Feet per second.	Smeaton and Rouse.	Circular surface.	Square surface.	Triangular surface.
0	0.	0.	....	....	....
1	1.47	0.005	0.003	0.003	0.004
2	2.93	0.02	0.014	0.014	0.014
3	4.4	0.044	0.03	0.031	0.032
4	5.87	0.079	0.054	0.055	0.057
5	7.33	0.123	0.085	0.086	0.088
10	14.67	0.492	0.339	0.345	0.353
12	17.6	0.711	....	....	....
15	22.	1.107	0.763	0.777	0.795
20	29.34	1.968	1.356	1.382	1.413
25	36.67	3.075	2.119	2.159	2.208
30	44.01	4.429	3.052	3.109	3.18
35	51.34	6.027	4.154	4.232	4.328
40	58.68	7.873	5.425	5.527	5.653
45	66.01	9.963	6.866	6.996	7.155
50	73 35	12.3	8.476	8.637	8.833
60	88.02	17.715	12.208	12.437	12.719
75	110.	27.65	....	....	....
80	117.36	31.49	21.701	22.11	22.613
90	132.03	39.852	....	....	....
100	146.70	49.2	33.908	34.546	35.332

At the last meeting of the British Association Mr. T. Hawksley, C. E.,

submitted the following formula and table:

Let v=the velocity of the current in feet per second.

h=the height through which a heavy body must fall to produce the velocity v.

w=the weight in pounds of a cubic foot of the impinging fluid [for atmospheric air averagely about 0.0765 lbs.]

g=32, the co-efficient of gravity.

Then $h=\frac{v^2}{2g}$; and since p the pressure of a fluid striking a plane perpendicularly, and then escaping at right angles to its original path, is that due to twice the height h [Daubuisson's Hydraulics; Rouse's Experiments] we have simply

$$p=\frac{wv^2}{g}$$

$$=(\text{for atmospheric air})\frac{0.0765v^2}{32}$$

$$=\left(\frac{v}{20}\right)^2 \text{ very nearly.}$$

From this easily-remembered formula the following Table of Pressures is constructed:

Velocities.		Pressure in Pounds per square foot.
Feet per second.	Miles per hour.	
10	8	0.25
20	13.6	1.00
30	20.4	2.25
40	27.2	4.00
50	34.0	6.25
60	40.8	9.00
70	47.6	12.25
80	54.4	16.00
90	61.2	20.25
100	68.0	25.00
110	74.8	30.25
120	81.6	36.00
130	88.4	42.25
140	95.2	49.00
150	102.0	56.25

In general, only these, the maximum pressures, are required; but sometimes, as in the case of the inclined sail of a windmill or ship, or the roof of a building, the diminished pressure upon a surface placed obliquely to the *effective* current is needed; we have then

$$p=\left(\frac{v \sin \theta}{20}\right)^2$$

in which v=the absolute velocity with which the air strikes the receding plane; and θ=the internal angle made by the obliquely-placed surface and the direction of the impinging wind.

It will be seen that the pressure calculated by Mr. Hawksley exceed Smeaton's and Hagen's. But while the committee appointed to consider the subject, after the destruction of the Tay Bridge, recommend that a maximum wind pressure of 56 lbs. per square foot should be assumed for railway bridges and viaducts, Mr. Hawksley says it is certain that a wind pressure of even 40 lbs. on the square foot is unknown in these islands, because, as may be readily shown, this intensity of pressure would have sufficed to overthrow most of the long-existing factory chimneys, to overset post windmills, and to scatter the greater number of the slighter-built domestic and other structures, which have nevertheless "weathered many a storm," and still remain intact. He considers that for structural calculations a maximum wind pressure of 40 lbs. per square foot may be very safely adopted, notwithstanding some reported anemometrical observations to the contrary. Tredgold also recommends that 40 lbs per square foot should be allowed, and his figures have been adopted by Professor Rankine.

A NEW ELECTRIC LIGHT REGULATOR.—In order to economise power in electric lighting it is of prime importance to have a regulator which will control the generating mechanism in such a way that the current supplied to the circuit will be just sufficient for the light required, or in other words, for the lamps to be lit. A novel device for this purpose has been exhibited recently at Messrs. Denny and Co.'s Engine Works, Dumbarton, by Mr. Joshua Horton, the Glasgow representative of the British Electric Light Company. It is specially intended for incandescent lights, such as those of Maxim, Swan, and Edison, and it operates so well that whether there are one or thirty lamps in circuit the feeding current is proportioned to the number. This is shown by the appearance of the lights to the eye, or their intensity as taken by the photometer, and also by a current meter. Moreover, the amount of work done by the engine is likewise proportioned to the amount of lamps in circuit. Mr. Horton's plan has been patented, and we are not yet at liberty to give the details; but it is quite independent of the ordinary resistance coils substituted for the lamps.

ECONOMY OF ELECTRIC LIGHTING BY INCANDESCENCE.

Thesis of JOHN W. HOWELL, Class of 1881, Stevens' Institute of Technology.

I.—Economy of the Generator. II.—Economy of the Conductor.
III.—Economy of the Lamps.

In writing this thesis I have endeavored to determine as nearly as I was able the cost of electric lighting by incandescence. Owing to the interest attached to the subject, and the lack of data upon which calculations can be based, I have endeavored to consider the subject in all its details, and have taken every precaution that suggested itself to guard against error.

The data given are sufficient to calculate the number of lamps to be obtained from each indicated horse power in a steam engine; beyond this I have not attempted to go, as my experience is insufficient to enable me to make any further determinations.

EFFICIENCY OR THE GENERATOR.

The generator tested was one of the latest pattern devised by Mr. Edison. It differs from the generators heretofore in general use, principally in the substitution of bars of copper for wires in the armature, which make the resistance of the armature very low and also economizes space, as the bars have a trapezoidal section, and when in position there is only clearance enough to allow for the insulation between them.

In my experiments the field was excited by a current shunted from the main circuit, the relative resistances of the mains and magnet coils determining the amount of energy expended on the magnets, and consequently the intensity of the magnetization and the electro-motive force of the generator.

APPARATUS FOR MEASUREMENT OF THE MECHANICAL ENERGY TRANSMITTED TO THE GENERATOR.

In measuring the energy transmitted to the generator, the dynamometer built by the class of '79 was used. This was carefully standardized by supporting the pendulum in a horizontal position at a point 2 feet from the axis of the shaft, and weighing the pressure of the support upon a platform scale; the weight of the pendulum and support was 183.25; the weight of the support was 12.1; the weight of the pendulum was 171.2 lbs.

This gives us the force acting at the circumference of a pulley of 1 foot radius by multiplying 171.2 by the sine of the angle of deflection. This is a measure of the force transmitted through the gear at the top of the pendulum, and includes, beside the force required to turn the armature in the field of force, the force necessary to overcome the friction of the dynamometer bearing, and also the friction of the armature shaft in its bearings. In order to determine what part of the transmitted energy was lost in overcoming friction, a Prony brake was applied to the pulley of the armature, close beside the belt, while the generator was running. Removing the brushes to be sure no current was generated, we tightened the brake until the pendulum showed the same deflection that it did during the test; we thus made a direct substitution of the Prony brake for the retarding action of the lines of magnetic force upon the armature when the circuit was closed, and the force exerted by the arm of the brake, upon a platform scale reduced to the radius of the pulley, will be the force required to turn the armature in the field of force. Instead of measuring the pressure exerted by one arm of the brake upon a scale, we measured the lifting effort exerted by the other end upon a weight resting upon the scale. We placed a light counterweight upon the other end of the brake, to make the zero reading more definite, and in getting the zero we raised the counterweighted end, and let it down gently, rapping the center of the brake to prevent sticking.

Several readings fixed the zero between $35\frac{1}{2}$ and 35. Running at about the same speed as in the test, and tightening the brake until we got a deflection of 42°, we made several readings on the scale, which varied from 19 to $20\frac{1}{2}$. Using the highest zero reading and the lowest running reading, we get a force of $16\frac{1}{2}$ lbs. acting at a

distance of 2 feet from the center of the shaft; this reduced to the radius of the armature pulley gives $16\frac{1}{2} \times \frac{24}{5} = 79.2$ for the force acting at the circumference of the armature pulley. If no friction had intervened this force would have been $\frac{171.2 \times (\text{sine } 42° = 66.913)}{125} = 91.644$ lbs., showing a loss of 91.644—79.2=12.444 lbs., or $13\frac{1}{2}$ per cent. of the power transmitted.

This loss of $13\frac{1}{2}$ per cent. is caused by the friction of the dynamometer and the friction of the armature bearings. To get the force actually applied at the circumference of the pulley on the armature shaft, we must determine the friction of the dynamometer bearing alone. To do this we made a wooden brake of the same diameter as the driving pulley on the dynamometer that could run on a 10-inch pulley on the dynamometer shaft, we then clamped the Prony brake upon the dynamo pulley, and also clamped the belt on the dynamo pulley and passed it over the wooden brake. Running under these conditions and tightening the wooden brake on the 10-inch pulley until the pendulum showed a deflection of 42°, we measured the force acting at the circumference of the dynamo pulley and also at the circumference of the dynamometer pulley by the lifting effort of the Prony brake upon the weight on the scale. The object of this arrangement of brakes was to get the friction under the same conditions as those under which we ran the test. To get the zero reading in this case we clamped the Prony on the dynamo pulley, and loosened the wooden brake and counterweighted the other arm of the Prony brake, until the armature turned in its bearings; then letting it come to rest and rapping the bearings of the dynamo and dynamometer, we determined the zero reading to be 33 lbs. Several readings fixed the readings for 42° at 16 lbs., therefore the force acting at the circumference of the dynamo pulley was $(33-16) \times \frac{24}{5} = 81.6$, showing a loss of 91.644—81.6 =10.044 lbs., or 10.9 per cent. of the total energy transmitted.

APPARATUS FOR THE MEASUREMENT OF ELECTRICAL ENERGY.

The resistance over which the generator worked consisted of three strands of iron wire in multiple arc, each of which was .104″ in diameter. These were stretched from one gallery of the shop to the other in the open air.

In measuring the resistance of the different parts of the circuit wires were led from the binding posts of the generator to the Wheatstone bridge, then by breaking the connection with the armature and magnet coils, we could measure the resistance of the line, or by breaking the connections with the line and magnets we could measure the resistance of the armature and leaders, or by breaking the connections with the armature and the line we could measure the resistance of the magnet coils.

The electrical energy developed in the circuit was determined by three methods:

1st. By a voltameter, or a copper-depositing cell.

2d. By a calorimeter.

3d. By measuring the electro-motive force and resistance.

FIRST METHOD.

The voltameter consisted of a glass jar large enough to hold six plates of copper, 7″×8″.

These were placed $\frac{1}{2}$″ apart, and held in place by a light wooden frame. They were connected alternately to the positive and negative wires from the generator. This method of arranging the plates brings both sides into action, gives a large area of plate, and makes the resistance of the cell very low and the consequent heating very little. By means of mercury connections the voltameter could be thrown into or out of circuit instantly without breaking the current, and the leaders were so proportioned that throwing it in and out did not alter the resistance of the circuit.

In calculating the current from the weight of copper carried from one set of plates to the other, the weight gained by the negative plates was considered as the weight carried over, and the constant .32456, given by Sprague (Jenkin gives .324) for the amount of copper in milligrams carried over in one second by a current of one Weber. Before making the test, the current was passed through the voltameter for some time, in a direction opposite to that in which it was passed during the test, to insure that

the copper carried over during the test was copper that had been deposited before, otherwise energy may be lost in separating the copper from the positive plate.

SECOND METHOD.

In determining the electrical energy by the second method, a calorimeter was used which consisted of a cylindrical vessel of galvanized iron encased in a wooden jacket, and so supported as to leave an air space of about $\frac{1}{2}$ an inch on all sides between the calorimeter and the jacket. This prevented any great conduction of heat from the calorimeter to external objects; still some heat must be wasted in heating the calorimeter and the surface it rests upon.

To determine the amount of heat thus wasted 55 lbs of water was put in the calorimeter, and its temperature carefully determined it was 19.85°C. A large pail of water was then heated to 54.3°C, and $18\frac{3}{4}$ lbs. were poured into the calorimeter. This made the weight of water in the calorimeter about the same as was used in the test, and the same part of the calorimeter was heated in each case, the final temperature of the water being 28.50°C, the range of temperature used in the test was included in this range. The heat contained in the water poured into the calorimeter may be represented by $18.75 \times 26.2 = 491.25$. Of this $55 \times 8.65 = 475.75$ went to raise the temperature of the water in the calorimeter, and the remainder 155 must have been imparted to the calorimeter. As the range of temperature in the calorimeter was 8.65°, 1.78 of these units were required to raise the temperature 1°, or the same amount of heat was used in heating the calorimeter as would be required to raise 1.78 lbs. of water through the same range of temperature; therefore the proper correction may be applied by adding 1.78 lbs. to the weight of water in the calorimeter.

To measure the heating effect of the current, a coil of copper wire was put into the calorimeter, the resistance of which was exactly .1 $\frac{1}{10}$ Ohm, at 74° F. The chief source of error in a calorimeter test of this kind is the tendency of the current to pass from one part of the wire to another through the water, instead of passing through the wire. This in itself is not a source of error if we measure the resistance of the coil in the water, but in so passing, it may carry metal from one part of the wire to another, and the energy so used cannot be calculated, and is lost; to obviate this difficulty distilled water was used, the resistance of which is much higher than ordinary water. The resistance of the coil measured in the water did not differ perceptibly from its resistance in the air, and at the close of the test no evidence of copper having been carried from one part to the other was discernable. To determine the range of temperature during the test, a Fahrenheit thermometer was used that was graduated to fifths of degrees, but the graduation was so plain that twentieths of a degree could easily be read. In order to be certain that the temperature of the water was uniform throughout a pump was placed in the center of the calorimeter, which consisted simply of a copper tube about $1\frac{3}{4}$" in diameter, its bottom was $\frac{1}{2}$" above the bottom of the calorimeter and contained a valve opening downward; the piston also carried a valve opening downward. The water in the calorimeter covered the top of the tube, and by this means the water was taken from the surface when it is warmest, and carried to the bottom, where it is coldest. The circulation thus obtained was very perfect, as shown by some ink drops put in the pump barrel.

THIRD METHOD.

In determining the electrical energy by he third method, the electro-motive forcet was measured between the binding posts of the generator, by means of a Thomson high-resistance galvanometer. As a standard of electro-motive force, Latimer Clark cells were used, four of which were made up new for the purpose. These agreed with each other very closely, and in using them they were connected in series, thus getting their combined effect, and averaging their errors.

In using them they were allowed to charge a condenser, and the condenser was then discharged through the galvanometer.

The deflection produced is an accurate measure of the current flowing through the galvanometer and consequently of the charge held by the condenser, which depends upon the electro-motive force of the terminals connected with the condenser. To connect the condenser alternately with the cells and the galvanometer, a simple switch was used by which the change could

be made instantly. In making the test part of the condenser of $.2\frac{2}{10}$ microfarad capacity wire used and four standard cells in series. The damping magnet of the galvanometer was then adjusted until the discharge of the condenser produced a deflection of 291 divisions, as the electromotive force of the cell is 1,456 volts and four in series were used, the deflection corresponding to one volt was $\frac{291}{1.456\times 4}$ =50. The instrument being standarized in this way, the liability to error was very small; in use, however, $\frac{9}{10}$ of the current was shunted from the galvanometer, only allowing $\frac{1}{10}$ to pass through, thus getting five deflections to a volt.

The ends of all wires dipping into mercury were amalgamated with mercurous nitrate, which made the connections very perfect.

In measuring the resistances of the armature and of the armature and leaders, the Wheatstone's bridge was used, and Thomson's reflecting galvanometer in place of the small galvanometer usually employed. The resistance of the armature mains and leaders was between .17 and .18 Ohm. When the bridge indicated .17 the galvanometer showed a deflection of 29.5 divisions; when it indicated .18 the galvanometer showed an opposite deflection of 45. From this we get the resistance of the armature mains and leaders, .17395 Ohm.

The main alone measured .14460, leaving for the resistance of the armature and leaders to the binding parts .029 Ohm.

Leading wires being clamped on the commutator the resistance measured in several positions was .16207. These leaders measured .14604, leaving for the resistance of the armature alone .016 Ohm.

The resistance of the field magnet coils was 37. Ohms.

TEST BY VOLTAMETER.

Before making the test the generator was run for some time to allow the circuit to heat up, and the resistance of the line measured from time to time until it was found to remain constant. The voltameter was then introduced into the circuit and allowed to remain fifteen minutes.

During this time the speed of the dynamometer was determined for ten minutes, and the average speed computed.

The deflection of the pendulum was observed every three minutes and the average taken, although the variation was only one degree. At the end of the test the circuit was broken and the resistance again measured, and it was found not to have changed perceptibly.

The plates were then removed, washed in water, then in alcohol, and dried in a gentle heat. They were then weighed carefully.

DATA OBTAINED FROM THE TEST.

Weight of copper gained by negative plates =24,465 m. g.
Time of test = 15 minutes.
Weight gained per second = 27,183 m. g.
Average speed of dynamometer = 400.5 rev. per min.
Average deflection of pendulum=42° 20′.
Resistance of iron wire = .76 Ohm.
Resistance of iron wires and magnet coils in multiple are = .744 Ohm.
Total resistance of circuit = .744+.029= .773 Ohm.
Internal resistance of armature = .016 Ohm.

RESULTS OBTAINED FROM DATA.

Value of current in webers = $\frac{27.183}{.32456}$ = 83.753.
Electrical energy $(83.753)^2\times.773\times44.24$= 239880.726 ft. lbs. per minute.
Energy indicated by dynamometer 171.2 $\times$ (sin 42°=.67344) $\times$ 4505 $\times$ 6.2832 =290125.54 ft. lbs. per minute.
Friction of dynamometer and generator $290125.54\times.135=39166.9479$ ft. lbs. per minute.
Energy used in turning armature in field of force $290125.54\times855=250958.59$ ft. lbs. per minute.
Friction of dynamometer alone=290125.5 $\times.109=31623.68$ ft. lbs. per minute.
Energy actually applied to armature pulley $290125.54\times.891=258501.96$ ft lbs. per min.

Of the total electrical energy 239880.7 $\frac{.016}{.773}$=4965.189 appeared in the armature, $\frac{.744}{.773\times49.68}\times239880.726$=4647.39 in the magnet coils, and 230268.176 ft. lbs. per minute in the external circuit.

The efficiency of the generator is the ratio of the energy required to turn the

armature in the magnetic field, to the total electrical energy developed $= \frac{239880.726}{250958.59} = .955.$

The commercial efficiency is the ratio of the energy required to drive the machine (including friction) to the electrical energy which appears in the external circuit $= \frac{230268.169}{258501.96} = .8608.$

TEST BY MEANS OF THE CALORIMETER.

As in the voltametric test the generator was first run until the circuit was thoroughly heated, and the same care was taken to determine the speed and deflection of the dynamometer. When the calorimeter was thrown into the circuit an approximately equal resistance was thrown out so as not to change the total resistance too much. At the end of the test the resistance of the circuit was measured carefully as soon as the circuit was broken and before the wires became cooled.

DATA OBTAINED FROM THIS TEST.

Water in calorimeter = 77 lbs.
Connection for waste heat = 1.78 lbs.
Range of temperature = 79° − 69.8° = 9.2°F.
Specific heat for this range = 1.0015.
Average speed of dynamometer = 394 rev. per min.
Average deflection of pendulum = 43° 24′ (sin = .68709).
Time of tests = 16 minutes.
Resistance of iron wires and calorimeter coil = .68 Ohm.
This and magnet coil in multiple arc = .667 Ohm.
Total resistance of circuit .667 + .029 = .696.
Resistance of calorimeter coil = .1 Ohm.

RESULTS OBTAINED FROM THESE DATA.

Energy developed in calorimeter $= \frac{78118 \times 1.0015 \times 9.2 \times 772}{16} = 35022.897$ ft. lbs. per minute.

Total electrical energy
$35022.897 \times 6.96 = 243759.36$ ft. lbs. per minute.

Energy indicated by dynamometer $=$
$171.2 \times .68709 \times 894 \times 6.2832$
$= 291201.46$ ft. lbs. per min.

Energy used in turning armature in field of force
$291201.46 \times .865 =$
251889.265 ft. lbs. per min.

Energy actually applied to armature pulley
$291201.46 \times .891 =$
259460.5 ft. lbs. per min.

Of the electrical energy

$$243759.36 \times \frac{.016}{.696} = 5603.66$$

appeared in the armature

$$243759.36 \times \frac{.667}{.669 \times 54.41} = 4215.89$$

in the magnet coils; and 233939.81 ft. lbs. per minute appeared outside.

$$\text{Efficiency} = \frac{243759363}{251889.265} = 967.$$

$$\text{Commercial efficiency} = \frac{233939.81}{259460.5} = .901.$$

TEST BY MEASUREMENT OF THE ELECTRO-MOTIVE FORCE AND RESISTANCE.

In this test the electro-motive force was measured between the binding posts of the generator, and the external resistance was measured between the same points.

The deflection and speed of the dynamometer were measured at the same time, the electro-motive force was observed and the resistance was measured just before and after these observations and was the same in both cases.

DATA OBTAINED FROM THIS TEST.

Electro-motive force = 53 volts.
Resistance of circuit (external) .64 Ohm.
Resistance between binding posts .629.
Average speed of dynamometer, 355 rev. per min.
Average deflection, 42° (nat. sine = .66913).
Total resistance of circuit, .658.

RESULTS OBTAINED FROM THESE DATA.

Energy developed in external circuit
$\frac{(53^2)}{629} \times 44.24 = 197567.43$ ft. lbs. per min.

Total electrical energy
$197567.43 \times \frac{.658}{.629} = 206673.0295$ ft. lbs. per min.

Energy in armature

$$206673.029 \times \frac{.016}{.658} = 5025.5.$$

Energy in magnet coils

$\frac{(53^2)}{37} \times 44.24 = 3346.667$ ft. lbs. per min.

Energy in external circuit 198300.88 ft. lbs. per min.

Energy indicated by dynamometer

$171.2 \times .66913 \times 355 \times 62332 =$
$2553 + 9.04$ ft. lbs. per min.

Energy used in turning armature in field of force

$255519.04 \times .865 =$
221023.97 ft. lbs. per min.

Energy actually applied to armature pulley

$255519.04 \times .891 =$
227667.47 ft. lbs. per min.

$$\text{Efficiency} = \frac{206673.0295}{221023.97} = .935.$$

$$\text{Commercial efficiency} = \frac{198300.88}{227667.47} = .87.$$

Average efficiency, .951.

Average commercial efficiency, .887.

ECONOMY OF THE CONDUCTORS.

The economy of the conductors which convey the electricity from the generator to the lamps may be considered under two heads: first, the efficiency of the material, second, the efficiency of its dimensions.

The efficiency of any material is determined by its price and conductivity as compared with other materials. The two materials most commonly used for conductors are copper and iron. The present price of copper is about seven times the price of iron and its conductivity is about six times as great; thus the actual cost of a line of copper wire of a given conductivity is one-sixth greater than iron wire of the same conductivity. Copper wire, however, is much more uniform than iron wire; it is free from cinder streaks that are so common to iron wire, and is much more pliable and less bulky, and therefore less difficult to handle. For electric-light mains, which have to be frequently tapped, copper wire seems to be preferable to iron wire.

2D. THE EFFICIENCY OF DIMENSIONS.

This is determined by the cost of the conductor and the loss of energy in the conductor. As the energy developed in different parts of the circuit varies directly as the resistance of these parts, some energy must appear in the conductors. This energy appears as heat, and is lost.

The most efficient dimensions of the conductors depend upon the amount of energy to be transmitted and the distance which it is to be transmitted.

To secure maximum efficiency, therefore, we would have to calculate the most efficient size under all conditions as to number of lamps and distances. Knowing, however, the conditions most usually met in practice, we can determine that loss of energy in the conductors, which is usually most efficient and expressing this loss as a percentage of the total energy transmitted, calculate the size of our conductors upon this basis by making the resistance of the conductors the same percentage of the total resistance of the circuit, as the loss of energy allowed is of the total energy transmitted.

Thus, when we wish to calculate the dimensions of our conductors necessary to convey the current to a given number of lamps a given distance, allowing a loss of $\frac{1}{n}$ of the total energy, we must determine the resistance of our lamps and make the resistance of our conductors $\frac{1}{n-1}$ part of the resistance of the lamps.

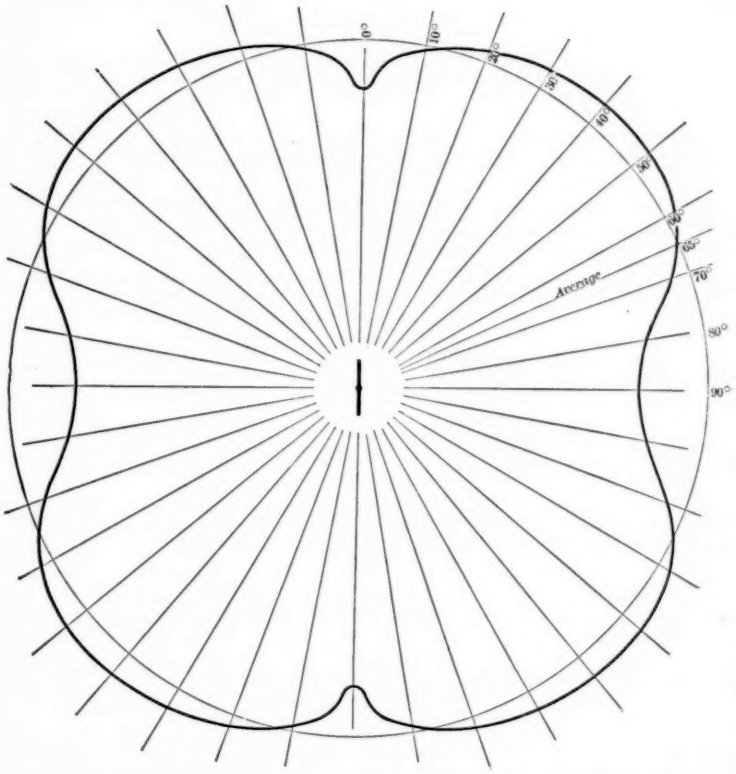
Thus we see that the cost of the conductors necessary to carry the current for a given number of lamps a given distance varies inversely as the resistance of the lamps, and although we can make a high or a low resistance lamp of the same economy, it will cost less to convey the currentto a given number of high-resistance lamps a given distance, than it will to convey the current to the same number of low resistance lamps the same distance.

ECONOMY OF THE LAMPS.

The economy of the lamps is determined by the energy consumed and the amount of light produced; in determing the energy consumed in the lamps, the electro-motive force was measured between the terminals of the lamps, and also the resistance, and the energy determined in foot pounds per minute by the formula $\frac{e^2}{R} 44.24$. In measuring the electro-motive force the same arrangements were used as in determing the electro-motive force of the generator, but the damping magnet was adjusted to give three units of deflection to a volt instead of five. To measure the

resistance of the lamps when burning, the current was divided into two parts, one part was passed through the lamp and the other through a variable resistance, when both were passed through a differential galvanometer, but in opposite directions; when the current was the same in both branches, the needle of the galvanometer would indicate zero. As the electro-motive forces of the two branches were equal, their currents were equal, when their resistances were equal, so by altering the variable resistance until the needle came to zero, and measuring the variable resistance we thus determined the resistance of the lamp while it was burning. This variable resistance was measured each time before it cooled.

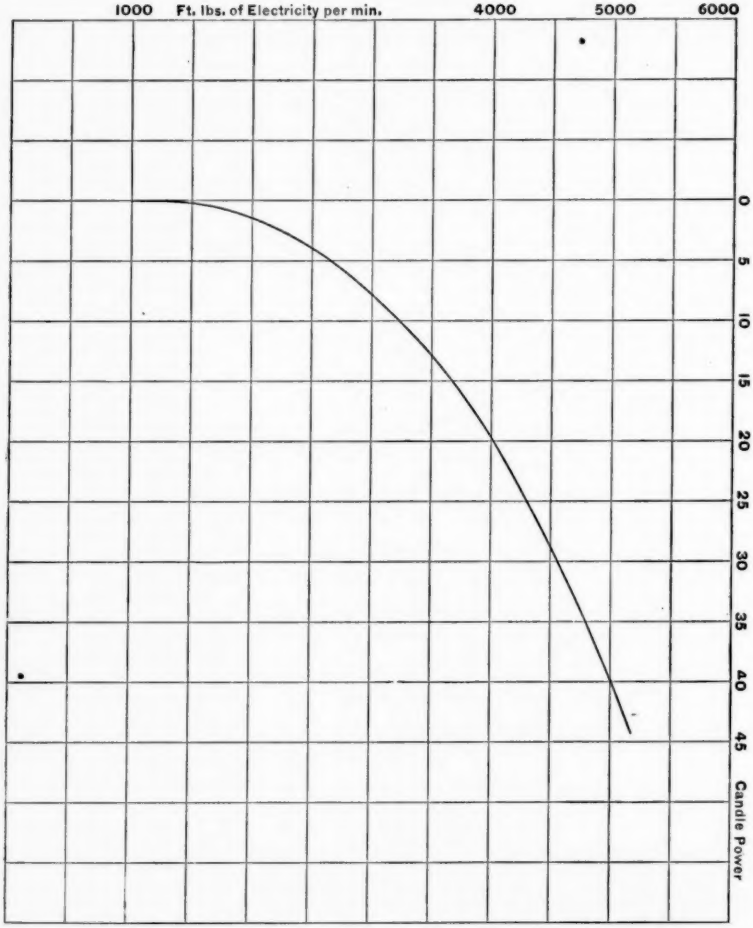
As the light given out in a horizontal plane varies at different angles, the angle of average illumination was first determined for the lamp used, which was the Edison lamp. To determine this angle, the candle power was measured every 10° through a quadrant, and the candle power observed laid off on a suitable scale on lines radiated from a point. A curve was drawn through the points thus determined, and the four quadrants being made symmetrical, its area was determined and a circle of equal area drawn about the point from which the lines radiate. The points where this circle cut the curve determine the angle at which the candle power is the same that it would be if the light were evenly distributed.



CURVE SHOWING ILLUMINATION OF EDISON'S LAMP IN A HORIZONTAL PLANE.

Having determined the angular position of these points with reference to the plane of the carbon, all measurements were made with the axis of the photometer in this angle.

To insure that the lamp was in this position, it was twisted until the shadow of the carbon fell on the center of the disc and then turned through an angle of 65°, which the curve shows to be the proper angle. All measurements of lamps were made at the angle of equal illumination.



CURVE SHOWING RELATION BETWEEN ECONOMY AND INCANDESCENCE.

In order to determine the economy of a lamp at different degrees of incandescence, an Edison lamp was measured at intensities ranging from a dull red to 40 candle power, and the results plotted in a curve show a rapid rise in economy as the candle power increases. While the economy of a lamp increases with incandescence, its life shortens, but as I have had neither time nor opportunities for life tests, I cannot give data for life at various degrees of incandescence.

Mr. Edison's standard of illumination has been 16 candle power, and his aim has been to produce a lamp that will give good economy and a reasonable life at that candle power.

To determine the energy consumed by these lamps when burning at their normal candle power, five lamps, as made at pre sent by Mr. Edison, were tested with the following results:

TABLE SHOWING ENERGY CONSUMED BY EDISON LAMPS.

	Candle Power.	Volts.	Ohms.	Foot-pounds of Electricity per minute.
1	16	98.66	135.5	3178 –03
2	16	98.66	142.5	3021–91
3	16	99.	140.5	3107–41
4	16	98.	148.5	2861–15
5	16	99.33	131.5	3319–32

Showing an average of 3,097–564 ft. bs. of electricity per minute, or 10.65 lamps per h. p. of electricity, giving 170 candles per h. p.

Mr. Edison gets 10.65 lamps per horse power of electricity, but as he allows a loss of 10% of the electrical energy used in the lamps upon the conductors, he gets 9.68 lamps for each h. p. of electricity generated. As the average commercial efficiency of this generator is .887, this gives him 8.58 lamps per dynamometrical h. p.

The report of the Board of Commissioners of the Millers' Exhibition, held in Cincinnati just one year ago, gives the results of the trial of three modern steam engines.

These results show an average for the three engines of .878 of the indicated power converted into useful work; using this factor for the conversion of dynamometrical into indicated horse power, we find that Mr. Edison gets 7.62 lamps per indicated horse power.

THE INTER-OCEAN CANAL.

By W. E. DAUCHY, C.E.

From Papers of the Pi Eta Scientific Society.

THE subject of an inter-oceanic canal across the American Isthmus is by no means a new one. Ever since Balboa made his way across this narrow strip of land, and discovered the Pacific Ocean lying beyond, the possibility of joining the two oceans by a navigable water-way has been more or less talked of.

As the subject is being brought prominently before the public at the present time, I propose to give you a brief summary of the work that has been done in making explorations and surveys, together with a few remarks on M. De Lesseps' proposed canal.

At first it may seem strange that so little is known of the American Isthmus, as it was there that the first settlements were made upon the continent, but when we consider the character of the country, it is not so much to be wondered at. Nature has here done all she can to defy exploration. The whole surface of the country is covered with a dense growth of forest, which is so thickly interwoven with vines and vegetation of every character, that it is in many places impossible for a man to walk through it without cutting his way at every step. These forests are the abodes of fevers, which are disastrous to explorers. Vegetation has such a rapid growth that even though a path be cut through the forest, unless it is continually used and kept trimmed, it is in a few weeks so covered with a new growth as not to be discernible. As a result, a knowledge of the country away from the sea-coast and the usual routes of travel, has been difficult to obtain.

During the past thirty years numerous explorations and surveys have been made of all feasible canal routes from the Isthmus of Tehuantepec to the Napipi River. This work has been carried on by the United States Government, by foreign Governments, and by private citizens. Commencing with the work done by the Government of the United States, the following is a list of the surveys and reconnoissances that have been made, taking them in their geographical order, from the north and west to the south and east:

I. An instrumental reconnoissance of the Isthmus of Tehuantepec by Capt. R. W. Schufeldt, U. S. N., in 1872. This route was found to be 144 miles in length, and the number of locks required 140.

II. An examination, survey and definite location of a canal route from the vicinity of Greytown, via Lake Nicaragua and the Rio del Medio and Rio Grande, to Brito, made by Commander E. P. Lull, U. S. N., in 1872-3, with some preliminary work by Commander Chester Hatfield, U. S. N., in 1872. The length of the actual canal required by this route was found to be 67.75 miles. Slack water navigation by means of dams in the bed of the San Juan River for 63 miles, and lake navigation for 56.5 miles. This plan involves the construction of four dams, with an average height of 29.5 feet, and an aggregate length of 1,320 yards, and of twenty locks of an average lift of 10.28 feet. It also requires the construction of two harbors at the termini, to insure a smooth and safe entrance and exit to and from the canal.

III. An examination, survey and definite location of a canal route from Navy Bay to Panama, by Commander E. P. Lull, U. S. N., in 1875. This route follows the Chagres River to Matachin, and from there follows the line of the Panama Railroad to Panama, crossing the divide by the same pass through which the railroad runs. This is the route by which M. De Lesseps proposes to build his canal, and of which I shall say more further on.

IV. Examination and surveys of the San Blas route by Commanders T. O. Selfridge and E. P. Lull, U. S. N. In 1870 Selfridge made a survey from the Gulf of San Blas on the Atlantic side towards the River Chepo. And in 1875 Lull, commencing on the Pacific side, made an examination of the River Chepo, and from there towards the Gulf of San Blas.

V. Several tentative instrumental lines were run in 1871 by parties under the direction of Commander Selfridge, in the vicinity of Caldonia Bay across the Cordilleras to the waters of the Sucubti and Morti Rivers, tributaries to the Chuchanqui. A line from the southern extremity of Caldonia Bay was found to cross the divide at the elevation of 1,259 feet, and struck the bed of the Sucubti at a height of 553 feet. A line from the northern extremity of Caldonia Bay up the valley of the Sassardi and across the divide to the Marti, crossed at an altitude of 1,148 feet, and no indications of any pass was discovered under 1,000 feet.

VI. A barometrical reconnoissance was also made in 1871 by Commander Selfridge of the De Puydt route. The Atrata and Teyter Rivers to be connnected by way of the Tanda River. The exact line advocated by De Puydt was followed for thirty miles. At this distance an elevation of 638 feet was reached, and the mountains of the divide were plainly visible beyond. The observations were taken with great care. Three mercurial barometers were used, one at the sea-level was observed at short intervals during the whole work; the other two were carried by the party, and bench marks were established, one barometer remaining at each bench until the other had reached the next, and until sets of different observations had been obtained.

VII. Tentative instrumental lines were run in 1871 by parties under the direction of Commander Selfridge from the east coast, by the Atrato, Cacarica, Peranchita Rivers, and from the west coast via the Tuyra and Cue Rivers across the divide. These lines crossed the divide at an elevation of 712 feet.

VIII. An instrumental examination of the Truando was made by Lieutenant Michler, U. S. A., and Lieutenant Craver, U. S. N., in 1856-7, and by them was reported upon as unfavorable.

IX. An instrumental reconnoissance of the Napipi and Cuia Rivers was made by parties under the direction of Commander Selfridge in 1871 and 1873. Also a reconnoissance of the Atrato River to the town of Quibdo.

X. Tentative examinations and a definite location of a route by way of the Napipi and Daguado Rivers were made in 1875 by Lieutenant Frederick Collins, U. S. N.

Of the above work done by the United States Government, actual instrumental locations were made at only three points, Nicaragua, Panama, and the Napipi. The tentative lines in other places were only carried sufficiently far to demonstrate their impractibility—or manifest inferiority.

Seven parties have been sent to the Isthmus at different times by Frederick M. Kelly of New York, who has spent a fortune and devoted years of his life to the study of the subject of a canal across the Isthmus.

The first party was sent out by Mr. Kelly in 1852, and was in charge of John C. Trautwine of Philadelphia. Entering the Gulf of Darien, Mr. Trautwine ascended the Atrata River 220 miles to Quibdo, and from thence advanced to the Raspadura Isthmus. He descended the San Juan to the Pacific and thus completed a careful survey from ocean to ocean 360 miles in length. Retracing his steps to Quibdo, he examined several passes leading to the Pacific by the Napipi, Beando, Pato and other rivers, and returned to New York and reported against the route.

In 1853 Mr. Kelly fitted out two engineering parties, and placed one in charge of Noah B. Porter, and the other in charge of Colonel James C. Lane, and instructed them to follow up Mr. Trautwine's survey to Quibdo, and from thence examine other passes leading to the Pacific higher up or lower down the Atrato at that place. They returned and reported against the route.

In 1854 Mr. Kelly sent out a fourth party in charge of Colonel Lane with instructions to ascend the Atrato to its confluence with the Truando, and from there to level across the country to Kelly's inlet on the Pacific. This survey proved a failure as the whole party were so reduced by sickness contracted at Aspinwall that Colonel Lane with but one man capable of doing duty could only reach the foot of the Cordilleras on the Atlantic side.

The following year Mr. Kelly sent out a fifth party under the charge of Captain William Kennish. This party crossed the Isthmus of Panama and commenced work from the Pacific side, at about 6° 57′ 32″ north latitude. Mr. Kennish succeeded in finding a feasible route for a canal 200 feet in width, 30 feet deep and including a tunnel through the Cordilleras.

In 1863 Mr. Kelly, assisted by Mr. Cyrus Butler and Mr. Luke T. Merrill of New York sent out Mr. Norman Rude to examine the San Blas route. Mr. Rude ran a barometrical line for the purpose of obtaining approximate heights and distances only. This resulting favorably, Mr. Kelly in 1864 sent out his seventh party, in charge of Mr. A. McDougall, to run a line of chains and levels. Commencing on the Pacific side they ascended the Bayano River to the great bend, and from there via the Mamoni, crossed the mountains to within three miles of the Gulf of San Blas on the Atlantic, where they were stopped by the Indians, and had to turn back. They reported the distance about thirty miles from ocean to ocean.

Several surveys have been made by English and French engineers. During the years 1877 and 1878 a large party of French engineers, in charge of Lieutenant Lucien N. B. Wyse, made several careful surveys between the Gulf of San Miguel and the Atlantic. They also examined the Panama and other routes.

In 1843 the French Government sent out Messrs. Garella and Courtenes to make examinations. And in 1865 M. de la Charme surveyed a line from the Gulf of Darien to the Gulf of San Miguel, via the River Tuira.

In the same year M. De Puydt, a French engineer, reported the discovery of a favorable route from the port of Escondido to the Tuira, and thence to the Gulf of San Miguel. This route was afterwards found by Commander Selfridge, U. S. N., to be impracticable. As early as 1827 explorations were made by Floyd and Falmark, engineers who were under the orders of General Bolivar.

These surveys and explorations have given the world enough general knowledge of the possible routes, to enable it to decide upon the most feasible one. And it was ostensibly for this purpose that the Inter-National Canal Congress convened in Paris in May, 1879. During the proceedings of that body it soon became evident that a choice of routes was not to be made according to the merits of each. And M. De Lesseps, who was president of the congress, and who had never been to the Isthmus, and personally knew nothing about the route he was advocating, succeeded in forcing a decision in favor of the Panama route, and in favor of constructing a tide-water canal without locks. The American representatives all declined to vote, on the ground that only able engineers can form

an opinion after careful study of what is actually possible, and what is relatively economical to the construction of a ship canal.

In 1878, when Lieutenant Lucien N. B. Wyse was in the United States of Columbia, he went to Bogota and made a contract with the Columbian Government in the name of the Civil International Canal Society, of which the following are the principal provisions:

ARTICLE 1st. Provides that the Civil International Canal Society shall have the exclusive privilege for the construction of a canal across the territory of the United States of Columbia, between the two oceans. This concession is made under the following conditions.

1. The duration of the privilege shall be for ninety-nine years, reckoned from the day on which the canal shall be opened wholly or partially to the public service.

2. The Government of the public cannot construct by itself or concede to any company or individual the right to construct another canal across Columbian territory which shall put in communication the two oceans. If the grantees wish to construct a railroad as an auxiliary to the canal, the Government (save existing rights) cannot construct by itself, or concede to any other company or individual the right to establish another inter-oceanic railroad during the time conceded for the construction and use of the canal.

3. The necessary studies of the ground and route for the line of the canal, shall be made at the cost of the granteesby an international commission of engineers, in which two Columbian engineers shall take part. The commission shall determine the general route of the canal and inform the Columbian Government of the same, at the latest in 1881, unless extreme necessity, clearly proven, shall prevent.

4. The grantees shall then have a period of two years to form a universal stock company, which shall take charge of the enterprise.

5. The canal shall be finished and placed at the service of the public during the following twelve years, counting from the time of the organization of the company to undertake its construction. But the executive power is authorized to grant a farther maximum term of six years, if, in an extreme case beyond the control of the company, and after one-third part of the canal is built, they shall recognize the impossibility of finishing the work in the said twelve years.

6. The canal shall have the length, depth and all other conditions necessary in order that sailing vessels and steamers of 140 meters in length, a maximum beam of 16 meters, and drawing 8 meters of water shall, with lowered topmasts, be able to pass the canal.

7. All unoccupied lands which may be necessary for the route of the canal, the ports, stations, wharves, moorings, warehouses, and in general for the construction of the canal and service of the same, as well as for the railroad, should it be convenient to build it, shall be considered free to the grantees. These lands shall revert to the government of the republic with the canal and railroad, at the termination of the ninety-nine years.

8. There is also conceded for the use of the canal a strip of land two hundred meters wide on both sides of its banks throughout its whole length.

9. The grantees shall have the right to demand the expropriation by the government, according to the legal formalities in such cases, of all private lands through which the canal shall pass.

10. The grantees may establish and operate the telegraphic lines which they may consider useful as auxiliaries to the canal.

ART. 2d. Provides that within the term of twelve months, reckoned from the time in which the commission shall have presented the result of it definite studies, the grantees will deposit in the bank or banks of London, which the executive power may designate, the sum of seven hundred and fifty thousand francs as a security for the execution of the work.

ART. 3d. Provides that should the route for the construction of the canal, from one ocean to the other, pass north or west of the imaginary straight line which joins the cape Tiburon with Garachine Point, the grantees must arrange amicably with the Panama railroad company, or pay an indemnity which shall be established by the terms of the law which approves the contracts made between that company and the government of the republic.

ART. 4th. Provides that the govern-

ment of the republic shall bestow upon the grantees 500,000 hectares of unoccupied public lands, with the mines they may contain. The public lands lying along the margin of the canal to be divided into lots of a thousand or two thousand hectares, and the grantees having each alternate lot.

ART. 5th. Provides that the waters of the canal and the ports of the termini shall be neutral, and in case of war between other nations, or between one or other of these and Columbia, the transit of the canal shall not be interrupted.

ART. 6th. Provides that the entrance of the canal shall be vigorously prohibited to the war vessels of those nations which are at war with one another, and whose destination manifests their intention to take part in hostilities.

ARTS. 7th, 9th, 10th and 11th provide that no taxes or duties of any kind whatsoever shall be imposed upon any material used in the construction and use of the canal or upon any of their property, or upon the tonnage passing through the canal.

ART. 14th. Provides that all tolls shall be levied without exception or favor upon all ships in identical conditions; also that the principal tolls which shall be levied upon vessels shall not exceed the rate of ten francs for each cubic meter resulting from the multiplication of the principal dimensions of the submerged portions of the ship in transit, and that special tolls for navigation shall be reduced in proportion to the excess, when the net profits derived from it shall exceed 12 per cent. upon the capital employed in the enterprise.

ART. 15th. Provides that the government of the republic, in return for the privileges granted shall enjoy a participation equal to five per cent. of the gross product which shall accrue to the enterprise, according to the tariff which shall be fixed by the company.

After the meeting of the canal congress in Paris, M. De Lesseps organized a company for the construction of the canal, and obtained from the Civil International Canal Society the right granted them by the Wyse contract, for which the canal society received 1,000 shares of the stock of the canal company.

M. De Lesseps went to the Isthmus in December, 1879, and on the first day of January, 1880, fired a blast on the route of the proposed canal, and from that moment considered the work on his canal to have been started.

On his return from the Isthmus, M. De Lesseps came to this country and made strenuous efforts to induce capitalists to subscribe for shares in his canal company, but the whole affair has savored so much of an immense stock-jobbing operation, that he has failed to obtain that aid which he hoped to get from the United States.

The preliminary examinations of the work to be done, which were made when M. De Lesseps was on the Isthmus, were made in a hurried manner, and difficulties and obstacles have been slurred over. The most important one, perhaps, is the question of drainage. By referring to the accompanying map, on which is shown the route of the canal chosen by M. De Lesseps, you will see that it follows the course of the Chagres river for half the distance across the Isthmus, crossing and recrossing that stream several times. The Chagres river drains the whole Atlantic slope of the Isthmus for miles, and a canal at the sea level will, of course, take the place of the river to carry off the drainage of the country. M. De Lesseps proposes to govern this question of drainage by building a great dam in the vicinity of Cruces and there storing the water during the time of floods.

To a person unacquainted with the nature of the country, this solution of the drainage question may seem very plausible, but to one who has witnessed the floods that take place almost every year, at the close of the rainy season, it is hardly satisfactory.

The Chagres river has a great many tributaries entering it below the proposed location of the dam. Towards the latter part of the rainy season (which lasts from about the first of June to about the first of January), each of these tributaries becomes greatly swollen, pouring into the Chagres its share of water, drift, and sediment, and the latter river becomes a torrent, inundating its banks, and in some places flooding the country for miles.

During the month of November, 1876, one of these floods occurred raising the Chagres river between thirty and forty

feet. At that time the river was so swollen that it stopped all traffic over the Panama Railroad for a week. The line of the railroad follows the Chagres river from Gatun to Matachin. At the time of this flood a person could go the majority of the distance between the two places in a canoe right over the track. The water was up over the telegraph wires along the road, stopping all communication by telegraph for five days. Such floods as this occur nearly every year.

The route of the canal crosses the summit at Culebra through the same pass that the Panama Railroad now runs. The summit of the railroad is 280 feet above the sea level, and at that point the road runs through a cutting 24 feet deep, making the summit of the pass about 300 feet above the sea.

Another question to be considered is whether the amount of tonnage that will pass through the canal is such as M. De Lesseps claims. I think it is doubtful whether sailing vessels will use a canal, built by the Panama route, to the extent that is usually calculated. There are three things they will have to contend with: 1st. Prevalence of calms in Panama bay. 2d. Prevalence of calms at certain seasons in the Caribbean sea, and 3d. The existence of currents in the Caribbean sea. The two latter acting together are great sources of annoyance to sailing vessels trying to make the harbor of Aspinwall.

During the Summer of 1878, while I was on the Isthmus, we were looking anxiously for a vessel which was on her way from Boston to Aspinwall, with a cargo of ice, as the supply of that article was entirely exhausted. The vessel was ninety-one days making the voyage, and was sighted one morning at Aspinwall, and if the light breeze which was blowing at the time had continued, she could have made the harbor in a few hours. But what breeze there was died out, and the current which flows northeast along the coast, at that point, drifted her out to sea again, and it was nearly two weeks before she made the harbor.

In the month of October, 1878, the steamship "Colon," while making the voyage from New York to Aspinwall, broke the crank pin of her engine when within 500 miles of Aspinwall. She proceeded on her voyage under sail, making very good progress until one evening when she was about sixty miles from Aspinwall, the wind died out. The next day at noon, when the captain took an observation, he found the steamer was over 120 miles from Aspinwall, and she did not reach that place for several days, when the engineer had fitted up another crank pin, and she went in by steam.

The so-called harbor at Aspinwall, or, as it is sometimes called, Navy bay, or the bay of Limon, is in reality no harbor at all, but an open roadstead, and at certain seasons is subject to storms which come from the north, and at such times the harbor is no protection to vessels at anchor, or laying at the wharves.

When these storms occur all steamers put to sea to prevent going ashore, and what sailing vessels are in the harbor put out all the anchors they have, and do the best they can to ride out the storm, but the result usually is, if the storm be a severe one, that the majority of them are wrecked. To make the harbor secure, as it must of necessity be, to be used as the terminus of the canal, a breakwater will have to be built, narrowing the mouth of the bay. The bay of Panama is a good harbor in every respect. Tide-locks will, of course, have to be built at each terminus. The difference in elevation between high and low tide is about 24 feet in Panama bay, and between two and three feet on the Atlantic side of the Isthmus.

In speaking of the difficulties to be encountered in building a tide-water canal by the Panama route, I do not mean to say that they cannot be surmounted, but that they have been treated of in as light a manner as possible and a rose-colored appearance given to all estimates, in order to induce capitalists to engage in the undertaking is quite evident. M. De Lesseps appears to be going on with the undertaking, with what success remains to be seen.

In view of the opening of the St. Gothard Railway, it is proposed to connect the Adriatic with the Lago Maggiore by a system of canals, of which the termini will be at Venice and Magadino, in the Canton of Tessin. As the Po and the Cavour Canal can be utilized, the undertaking will be neither difficult nor costly, and a group of Italian bankers have promised their financial co-operation.

ON THE DYNAMO-ELECTRIC CURRENT, AND ON CERTAIN MEANS TO IMPROVE ITS STEADINESS.

By C. WILLIAM SIEMENS, D.C.L., F.R.S.

From Philosophical Transactions of the Royal Society.

On the 14th of February, 1867, I communicated a short paper to the Royal Society, describing the accumulative or dynamo-electrical principle of action, the conception of which I attributed to my brother Dr. Werner Siemens. When the paper was read, another paper followed by Sir Charles Wheatstone (sent in on the 24th February) also describing this principle of action, thus showing that the same line of thought had occupied that eminent philosopher.

In illustration of my paper I exhibited a machine of my design, embodying the accumulative principle of action, which furnished abundant evidence of the powerful nature of the current that could be thus produced. It consisted of two horseshoe electro magnets, between the poles of which a Siemens armature could be made to rotate, the machine being furnished with a handle or pulley for that purpose. A commutator was provided, by which the alternating currents set up in the rotating coil (after a first impulse had been given) were directed through the coils of the stationary electro magnets in a continuous manner, and proceeded thence outward to ignite a platinum wire of some 12″ in length, or to perform other work.

This machine, although the first of its kind, has done good service ever since its construction, having been found very efficacious in exciting powerful permanent magnets at the telegraph works of Siemens Brothers at Woolwich.

Since 1867 the accumulative principle has been employed in the machines of different makers, and one form of dynamo-electric machine, that of M. Gramme, differs very materially from the machine above referred to, and had met very deservedly with extensive recognition. M. Gramme embodied in his machine the principle of Professor Pacinotti's magnetic ring, which enabled him to produce powerful electric currents without much of the loss of energy caused in previous machines through the heating of the rotating armature.

Another modification of the dynamo-electrical machine is one devised by Mr. Von Heftner Alteneck, an engineer and physicist employed under my brother Werner Siemens, at Berlin. This machine differs from that first submitted by myself in several important particulars. Instead of the Werner Siemens armature, Von Heftner Alteneck adopted a rotating coil of iron wire wound with insulated copper wire in more than one direction, the several coils of wire being connected seriatim with the commutator, and through it, with the wire surrounding the soft iron bars, and with the electric lamp or other resistance on the outer circuit.

The advantage claimed for this mode of construction is that all the wire forming the rotating coil or helix is brought into the magnetic field, excepting only those portions crossing from side to side of the coil; and in order to reduce this unproductive resistance to a minimum, the rotating coil or helix has been made comparatively long, and the number of electro magnets has been increased generally to six or more.

The principal advantage of the dynamo-electrical machine over all other current generators consists in its power of producing currents of great magnitude, and of an intensity up to 100 volts, with a small primary resistance, and therefore with a comparatively small expenditure of mechanical energy. It labors, on the other hand, under the disadvantage that the power of the current depends, at a given velocity, upon the magnetic force developed in the electro magnets. This force depends upon the amount of current passing through the coils of the magnets, which in its turn is dependent in an inverse ratio upon the resistance in the outer circuit. If from some accidental cause the external resistance is increased, the electro-motive force of the machine, instead of rising to overcome the obstruc-

tion, diminishes, and thus aggravates the resulting disturbance. If, on the other hand, the resistance of the outer circuit diminishes, as in the case when the carbons of an electric regulator touch one another, the electro magnets are immediately excited to a maximum, and the electro-motive force of the machine is increased. The power absorbed and its equivalent, the heat generated in the circuit, is equal to the square of the electro-motive force divided by the resistance; hence the work demanded from the engine will be greatly increased, the machine may be dangerously overheated, and powerful sparks may injure the commutator. It is chiefly owing to this instability of the dynamo-electric current that its application to electric illumination has been retarded, and that magneto-electric machines and machines producing alternating currents have been again used, although they are inferior to the dynamo machine in the current energy produced for a given expenditure of mechanical energy.

The properties of dynamo-electric machines have been examined by several observers. Messrs. Houston and Thomson (Franklin Institute) compared the efficiency of the Gramme, Brush, and Wallace Farmer machines. Dr. Hopkinson (Institution of Mechanical Engineers, 25th April, 1879) examined a medium-sized Siemens machine, determined its efficiency, and expressed the electro-motive force as a function of the current. Herrn Mayer and Anerbach (*Wiedemanns, Annalen*, November, 1879) and M. Mascart have experimented on the Gramme machine, and Mr. Schwendler on both Gramme and Siemens machines.

The radical defect of the dynamo machine of ordinary construction, may be inferred from the results of these experiments. The remedy has, however, been in our hands from the time of the first announcement of the principle of these machines before the Royal Society, when Sir Charles Wheatstone pointed out that "a very remarkable increase of all the effects, accompanied by a diminution in the resistance of the machine, is observed when a cross wire is placed so as to divert a great portion of the current from the electro magnet."

Some of the constructors of dynamo machines, namely: Mr. Ladd in this country, and Mr. Brush in the United States of America, have taken advantage of this suggestion, the latter with the avowed object in view of obviating spontaneous changes of polarity in effecting electro precipitation of metals, and without perhaps having realized all of the advantages of which this mode of action is capable; others have refrained from doing so on account of difficulties resulting, as I shall endeavor to show, from an insufficient examination into some important physical conditions that require attention in order to realize economical results.

An ordinary medium-sized Siemens-Alteneck dynamo-electrical machine has wound on its rotating helix insulated copper wire of 2.5 m.m. diameter in 24 sections, representing a resistance of .4014 S. U.* The four electro-magnet coils connected seriatim are composed of copper wire of 5.5 m.m. diameter, presenting a total resistance of 0.3065 S. U.

If (as has frequently been done) the wires of this machine were to be connected as suggested in Sir Charles Wheatstone's original paper, thus making the outer circuit not continuous with but parallel to the coil circuit, and if the outer circuit had a resistance of one unit, it would follow that the total resistance to the current set up by the rotation of the armature would be reduced from

$$.4+.3+1.=1.7 \text{ to } .4+\frac{.3\times 1}{1+.3} = 0.61 \text{ unit,}$$

causing a great increase of current, the major portion (in the proportion of 10 to 4) would flow through the electro magnets, thus causing a great increase of heating effect. The resistance of the field magnet must therefore be greatly increased, but if it were attempted to increase that resistance simply by reducing the diameter of the wire, and increasing the number of convolutions until the same thickness of coil was obtained, the magnetic excitement and with it the electro-motive force of the current produced at a given velocity of rotation

* The resistance coils used in these experiments were graduated according to the mercury system introduced by Dr. Werner Siemens, and adopted by the Telegraphic Convention at Vienna in 1868. The B. A. unit was determined in 1874 by Kohlrausch to be 1.0493 S. U., or combined with Lorenz's value of the S. U. afterwards adopted, 0.9797×10^9 C.G. S. units—as much as 2 per cent. below its ascribed theoretical value. Later determinations by H. F. Weber (Phil. Mag., March, 1878) makes the S. U. to be equal to 0.955×10^9 C. G. S. units, and thus the Ohm to be 0.2 per cent. higher than its ascribed value; if this latter value is used, the numerical results must be correspondingly altered.

would suffer a material decrease. The current flowing through the helix coil would moreover have to divide itself, and in order to reach the same limit in the outer circuit its intensity in the helix coil would have to be increased, causing it to heat more readily than before. It was necessary, therefore, to raise the effect of the magnet current to the same level as before with as small a proportion of the helix current as possible, in order to leave a maximum proportion of the current for the outer circuit. In order to effect this, the magnet bars had to be increased in length, and placed further apart so as to provide room for coils of greatly increased weight and dimensions; at the same time the helix wire had to be increased in diameter to give room for the aggregate current, but in reality I found it advantageous to increase the diameter of the same in a much greater proportion.

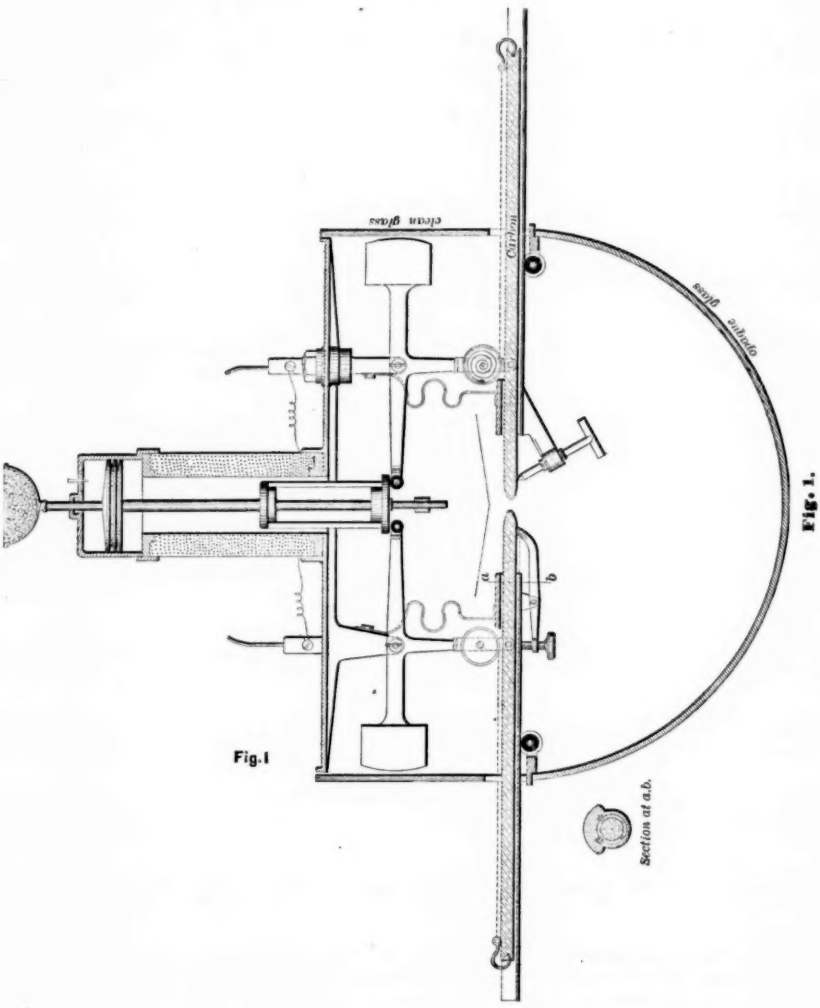


Fig. 1.

Fig. 1

These general conditions having been determined by preliminary experiment, Mr. Lauckert, electrician engaged at my works, undertook a series of comparative experiments which are given in the appendix attached to this paper, and the results are given numerically and exhibited in curves. On examining the curves it will be remarked:

1. That the electro-motive force instead of diminishing with increased resistance, increases at first rapidly, then more slowly towards an asymptote.

2. That the current in the outer circuit is actually greater for a unit and a half resistance than for one unit.

3. With an external resistance of one unit, which is about equivalent to an electric arc when 30 or 40 webers are passing through it, 2.44 horse power is expended, of which 1.29 horse power is usefully employed; an efficiency of 53 per cent. as compared with 45 per cent. in the case of the ordinary dynamo machine.

4. That the maximum energy which can be demanded from the engine is 2.6 horse power, so that but a small margin of power is needed to suffice for the greatest possible requirement.

5. That the maximum energy which can be injuriously transferred into heat in the machine itself is 1.3 horse power, so that there is no fear here of destroying the insulation of the helix by excessive heating.

6. That the maximum current is approximately that which would be habitually used, and which the commutator and collecting brushes are quite capable of transmitting.

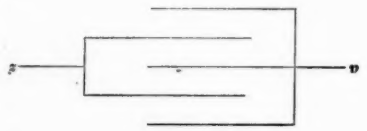
Hence I conclude that the new machine will give a steadier light than the old one, with greater average economy of power, that it will be less liable to derangement, and may be driven without variation of speed by a smaller engine; also that the new machine is free from the objection of having its currents reversed when used for the purpose of electro deposition.

The same peculiarity also enables me to effect an important simplification of the regulator to work electric lamps, to dispense with all wheel and clock-work in the arrangement, as shown in Fig. 1. The two carbons, being pushed onward by gravity or spring power, are checked laterally by a pointed metallic abutment, situated at such a distance from the arc itself that the heat is only just sufficient to cause the gradual wasting away of the carbon in contact with atmospheric air. The carbon holders are connected with the iron core of a solenoid coil, of a resistance equal to about fifty times that of the arc, the ends of which coil are connected with the two electrodes respectively. The weight of the core, which has to be maintained in suspension by the attractive force produced by the current, determines the distance between the electrodes, and hence the electric resistance of the arc. The result is that the length of the arc is regulated automatically so as to maintain a uniform resistance, signifying a uniform development of light.

APPENDIX.

The measurements of the electric currents were made with an electro dynamometer, the movable part of which consisted of a single turn of 4 m.m. wire, and the stationary coil of nine turns of the same.

To be able to reduce the electrical measurements into absolute power developed, it was in the first place necessary to determine the constant of the instrument in use. This was done in the following manner: Five copper plates of about $11'' \times 8''$ were connected as shown in the sketch.



These were carefully weighed and immersed in a solution of sulphate of copper. The machine was previously started, the time of immersion carefully noted, and the readings of the current taken every half minute. The plates were so arranged that the current entering at *a* and leaving at *z* deposited the copper on both sides of the plate at *z*. After a certain time the plates were taken out, quickly rinsed in water, and dried in sawdust. The plates were then carefully weighed again and the deposit calculated per degree reading on the instrument per second of time. Six independent measurements were taken with currents varying from 20 to 40

webers, and gave a mean of .000779 gramme of copper per second per degree reading. The differences of these measurements from the mean varied from 0.21 per cent. to 6.6 per cent., the mean of the differences being 1.98 per cent.

According to F. Kohlrausch (Pogg. Ann., Bd. cxlix., 1873) the quantity of silver deposited by the C. G. S. unit of electricity is 0.011363 gramme, and since the quantities vary as the equivalents of the metals deposited, we have

$$\frac{.011363 \times 63.5}{216} = 0.003340$$

gramme of copper.

One weber being $\frac{1}{10}$ C. G. S. unit, we have to divide by 10 the quantity of copper deposited by a current of one weber in one second, that is .000334 gramme, and dividing .000779 by .000334 we get 2.23323 webers for a degree reading of our instrument.

To be able to compare the machines having the new winding (*i. e.*, the wire on the electro magnets connected parallel with the outer circuit) with the ordinary machines, it was necessary to experiment on the relation existing between the power expended and the current produced with different resistances in circuit and different speeds.

A medium dynamo machine with 24 part commutator was used, the helix being wound with 336 convolutions of 2.5 m. m. wire, having a resistance of .4014 S. U. when measured in the machine. The electro magnets were wound with four layers of 5.5 m.m. wire, each having 32 convolutions, and therefore the four bobbins a total of 512 convolutions with a resistance of .3065 S. U.

The accompanying Tables Nos. 5, 6, 7, 8, and 9 give the details of the experiments made, which are shown graphically in the diagrams similarly numbered. The current in webers was simply calculated by multiplying the square root of the reading on the electro dynamometer with the constant of the instrument, *i. e.*, 2.3323.

To be able to calculate the electromotive force from the current in webers and resistance in Siemens' units, it was necessary to convert the S. U. into C.G.S. units by multiplying the same by $.9337 \times 10^9$. (This figure is given by Lorenz, Pogg. Ann., Bd. cxlix., 1873.) By again multiplying this resistance into the current we get, according to Ohm's law, the electro-motive force in C. G. S. units, and by dividing by 10^8 we get the E. M. F. in volts.

I have further calculated the total amount of work developed in the following manner:

Work done $= E \times C \times t$, or, which is the same, $C^2 \times R \times t$, where E is E. M. F; C, current; R, resistance; t, time.

From these calculations t is eliminated as it occurs in all the equations.

1 volt $= 10^8$ C. G. S. units.
1 weber $= \frac{1}{10}$ C. G. S. unit of current.
1 HP $= 7.46 \times 10^9$ C. G. S. units.

Therefore

$$\frac{1 \text{ volt} \times 1 \text{ weber}}{1 \text{ HP}} = \frac{10^8 \times 10^{-1}}{7.46 \times 10^9} = \frac{1}{746}$$

and if we multiply the E. M. F. in volts by the current in webers, and divide by 746, we have the actual work developed in horse power.

To find the actual work done in the outside resistance we use the formula $C^2 \times R$, of course having to reduce the resistance R into absolute C. G. S. units by multiplying by $.9337 \times 10^9$.

The machine with the new winding had a helix with 24 part commutator wound with 312 convolutions of 2.8 m.m. wire.

The electro-magnets being lengthened by 2″ to take bobbins $10\frac{1}{2}$″, instead of $8\frac{1}{2}$″ as on the ordinary machines, I had three sets of bobbins made, and had the same wound with different sizes of wire, viz.; 2.5 m.m., 2.8 m.m., and 3 m.m., having a respective resistance of 11.26, 7.563, and 4.46 S. U.

The accompanying Tables Nos. 1, 2, 3, and 4 show the experiments made with this machine with electro-magnets of 11.26 S. U. resistance; Nos. 10, 11, 12, and 13 with electro-magnets of 7.563 S.U.; and Nos. 14 and 15 with electro-magnets of 4.46 S. U. The helix in all cases having been wound with 2.8 m.m. wire with a resistance of .234 S. U. when measured in the machine.

The Tables marked 5, 6, 7, 8, and 9 refer to the dynamo machine wound in the ordinary way.

The Tables marked 16, 17, 18, 19, 20,

21, 22, and 23 show the results obtained with a machine having a helix wound with 288 convolutions of 3 m.m. wire and a resistance of .173 S. units. The electro-magnets, as before, had a resistance of 11.26, 7.563, and 4.47 S. U.

No. 1.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.

Electro-magnets: 3916 convolutions, 2.5 m.m. wire, 11.26 S. U. resistance (connected parallel to outer circuit).

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total Developed.	Developed in outer circuit.	
500	0.0	..	0.0	..	..	..	..	..	..	.205	..	..	..
"	.01	.25	.5	..	..	1.63	..	..	.3804	"	.000831	..	..
"	.02	.26	.5	..	..	1.63	..	..	.3957	"	.000864	..	..
"	.05	.28	1.0	..	..	2.33	..	..	.6091	"	.00190	..	..
"	.10	.34	1.5	..	..	2.86	..	..	.9079	"	.00348	..	..
"	.25	.48	2.0	..	..	3.30	..	..	1.479	"	.00654	..	..
"	.50	.72	14.0	1.0	12	8.80	2.33	8.08	5.915	.714	.0698	.0409	5.73
"	.75	.94	130.0	1.5	115	26.58	2.86	25.01	23.32	1.43	.881	.587	41.04
"	1.0	1.16	180.0	2.0	145	31.30	3.30	28.08	33.90	1.83	1.422	.987	53.93
"	1.25	1.36	145.0	2.0	125	28.08	3.30	26.07	35.65	"	1.342	1.063	58.08
"	1.5	1.56	135.0	3.0	115	27.09	4.04	25.01	39.46	"	1.433	1.17	63.93
"	1.75	1.75	132.0	3.0	102	26.79	4.04	23.55	43.77	"	1.592	1.21	66.12
"	2.0	1.94	120.0	3.5	95	25.55	4.36	22.73	46.28	1.73	1.585	1.29	69.94
"	∞	..	5.0	4.0	0	5.21	4.66	..	..	.714	..	..	..

No. 2.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.

Electro-magnets: 3916 convolutions, 2.5 m.m. wire, 11.26 S. U. resistance (connected parallel to outer circuit).

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
600	0.0	.24	0	..	..	..	..	..	..	.245	..	..	..
"	.25	.48	1	..	..	2.23	..	..	1.044	"	.0032	..	..
"	.50	.72	5	..	..	5.21	..	..	3.502	"	.0244	..	..
"	.75	.94	125	..	115	26.07	..	25.01	22.87	1.714	.799	.587	34.34
"	1.0	1.16	215	2.0	175	34.20	3.3	30.86	37.04	2.45	1.70	1.16	47.34
"	1.25	1.36	195	2.5	153	32.57	3.69	28.84	41.35	"	1.805	1.3	53.06
"	1.50	1.56	185	3.5	144	31.72	4.361	27.99	46.20	2.33	1.96	1.47	63.09
"	1.75	1.75	164	4.0	125	29.87	4.66	26.07	48.80	2.20	1.95	1.49	67.72
"	2.0	1.94	160	4.0	120	29.50	4.66	25.55	53.43	"	2.12	1.633	74.32
"	∞	11.50	6	5.0	0	5.71	5.21	..	65.66	1.10	.503	..	..

No. 3.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.

Electro-magnets: 3916 convolutions, 2.5 m.m. wire, 11.26 S. U. resistance (connected parallel to outer circuit).

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
700	0.0	.24	..	..	..	..	..	..	..	.29	..	..	..
"	.25	.48	4	..	..	4.66	..	..	2.078	"	.0129	..	..
"	.5	.72	11	..	..	7.74	..	..	5.203	"	.0540	..	..
"	.75	.94	285	5	255	39.37	5.21	37.25	34.56	2.57	1.82	1.3	55.58
"	1.0	1.18	325	6	280	42.05	5.71	39.03	46.33	3.47	2.61	1.9	54.75
"	1.25	1.36	300	6	250	40.40	5.71	36.88	51.3	"	2.77	2.13	61.37
"	1.5	1.56	276	6	205	38.75	5.71	33.39	55.81	"	2.90	2.09	60.23
"	1.75	1.75	230	6	170	35.37	5.71	30.41	57.79	"	2.74	2.03	58.50
"	2 0	1.94	215	7	158	34.2	6.17	29.31	61.95	3.28	2.84	2.15	65.54
"	∞	11.50	11	10	0	7.74	7.37	..	83.11	1.29	.862	..	..

No. 4.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.

Electro-magnets: 3916 convolutions, 2.5 m.m. wire, 11.26 S. U. resistance (connected parallel to outer circuit).

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned in to useful work
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
758	12.30	6.11	38	9.0	9	14.38	6.99	6.99	82.03	2.78	1.58	.752	27.26
756	8.90	5.21	49	8.5	14	16.32	6.77	8.88	79.38	2.93	1.74	.872	29.96
754	6.00	4.15	69	9.0	28	19.37	6.99	12.34	75.05	3.0	1.95	1.14	38.00
758	6.00	4.15	72	9.0	28	19.79	6.99	12.34	76.67	3.09	2.03	1.14	36.89
750	4.50	3.43	85	9.0	34	21.50	6.99	13.61	68.85	3.21	1.98	1.04	32.40
756	3.50	2.91	150	7.0	87	28.56	6.17	21.75	77.59	3.86	2.97	2.17	52.07
760	3.00	2.61	185	6.0	107	31.72	5.71	24.12	77.30	3.88	3.29	2.18	56.18
758	2.50	2.28	204	5.0	130	33.31	5.21	26.58	70.91	3.87	3.17	2.21	57.11
750	2.25	2.12	230	..	150	35.37	..	28.56	70.01	3.83	3.32	2.30	60.01
760	2.00	1.94	226	..	157	35.06	..	29.37	63.51	3.88	2.99	2.14	55.15
755	1.75	1.75	252	..	180	37.03	..	31.30	60.50	3.85	3.00	2.14	55.58
754	1.50	1.56	255	..	185	37.25	..	31.72	54.26	3.85	2.71	1.89	49.10
760	1.35	1.44	305	..	240	41.20	..	36.14	54.71	3.72	2.99	2.21	59.41
756	1.25	1.36	310	..	245	41.06	..	36.50	52.14	3.70	2.89	2.08	56.48
764	1.10	1.24	315	..	260	41.20	..	37.61	47.70	3.74	2.63	1.94	51.87
766	1.00	1.16	315	..	264	40.73	..	37.89	44.62	3.59	2.46	1.80	50.01
750	.90	1.07	285	..	238	39.37	..	35.98	39.33	3.06	2.07	1.46	47.71
765	.80	.99	235	..	205	35.75	..	33.39	33.04	2.50	1.58	1.12	44.80
760	.75	.94	208	..	185	33.64	..	31.30	29.52	2.48	1.33	.92	37.09
755	.65	.85	98	..	87	23.09	..	21.75	18.32	1.08	.567	.385	35.64
760	.60	.81	50	..	45	16.49	..	15.64	12.47	1.08	.275	.184	17.03
700	.55	.76	30	..	25	12.77	..	11.68	9.07	.43	.155	.094	21.86
752	.50	.72	12	..	10	8.07	..	7.37	6.36	.46	.069	.094	7.39
..	.40	.65	5	..	4	5.21	..	4.66	3.16	..	.0221	.0109	2.37
..	∞	11.50	12	12.00	..	8.07	8.07	..	86.64	..	.937	..	..

No. 5.

Helix: 24 part commutator, 336 convolutions, 2.5 m.m. wire, .4014 S. U. resistance.
Electro-magnets: 512 convolutions, 5.5 m.m. wire, .3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended.	Total developed.	Developed in outer circuit.	
750	∞	..	..	..	..	.306	..	..	..
"	8.9	9.61	1	2.33	20.90	"	.0653	.0605	19.77
"	6.0	6.71	1	"	14.59	"	.0455	.0408	13.33
"	4.5	5.21	1	"	11.33	"	.0353	.0306	10.00
745	3.5	4.21	7	6.17	24.25	.304	.205	.167	54.93
760	3.25	3.96	16	9.32	34.46	.620	.430	.353	56.90
758	3.0	3 71	26	11.89	41.18	.773	.656	.531	68.70
750	2.75	3.46	40	14.75	47.65	1.224	.942	.749	61.19
740	2.5	3.20	66	18.95	56.62	1.660	1.44	1.12	67.67
756	2.25	2 96	85	21.50	59.42	2.16	1.71	1.30	60.18
774	2.0	2.71	120	25.55	64.65	2.69	2.21	1.63	60.59
768	1.75	2.46	165	29.96	68.81	3.45	2.76	1.97	57.10
736	1.5	2.21	215	34.20	70.57	3.90	3.23	2.30	56.41
710	1.25	1.96	260	37.61	68.80	4.35	3.47	2.21	50.80
734	1.0	1.71	330	42 37	67.65	5.02	3.84	2.25	44.82
736	.9	1.61	520	53.17	79.92	6.16	5.69	3.16	51.29
"	.8	1.51	570	55.67	78.49	6.91	5.86	3.10	44.87
"	.75	1.46	625	58.31	79.48	6.91	6.21	3.19	46.16

No. 6.

Helix: 24 part commutator, 336 convolutions, 2.5 m.m. wire, .4014 S. U. resistance.
Electro-magnets: 512 convolutions, 5.5 m.m. wire, .3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended.	Total developed.	Developed in outer circuit.	
500	3.5	..	..	..	..	.257	..	..	..
496	3.0	3.71	1.5	2.86	9.90	.405	.0379	.0307	7.58
505	2.5	3.21	2	3.29	9.86	.515	.1434	.0338	6.563
516	2.0	2.71	9	6.99	17.68	.579	.165	.122	21.07
520	1.75	2.46	42	15.11	34.70	.796	.702	.500	62.81
490	1.5	2.21	60	18.06	37.26	1.20	.902	.612	51.00
496	1.25	1.96	120	25.55	46.75	1.82	1.61	1.02	56.04
490	1.0	1.71	180	31.30	49.97	2.30	2.09	1.23	53.47
490	.85	1.56	245	36.50	53.16	2.80	2.60	1.42	50.71
504	.75	1.46	280	39.03	53.20	3.08	2.78	1.43	46.42
502	.65	1.36	320	41.72	52.97	3.08	2 96	1.41	45.79
"	.60	1.31	340	43.01	52.60	3.58	3.03	1.39	38.83
"	.55	1.26	355	43.94	51.68	3.58	3.04	1.33	37.15
488	.50	1.21	385	45.76	51.70	3.58	3.17	1.25	34.92
"	.45	1.16	420	47.80	51.77	3.78	3.32	1.29	34.13
"	.40	1.11	491	51.63	53.49	3.98	3.70	1.33	33.42
"	.35	1.06	510	52.66	52.10	4.08	3.68	1.21	29.65
"	.30	1.01	600	57.12	53.89	4.28	4.12	1.22	28.51
"	.25	.96	630	58.54	52.46	4.58	4.11	1.07	23.36

No. 7.

Helix: 24 part commutator, 336 convolutions, 2.5 m.m. wire, .4014 S. U. resistance.
Electro-magnets: 512 convolutions, 5.5 m.m. wire, .3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended.	Total developed.	Developed in outer circuit.	
602	4.5	5.21	..	..	..	.246	..	..	..
"	3.5	4.21	..	..	..	.491	..	..	..
590	3.0	3.71	1	2.33	8.07	.602	.0252	.0203	3.372
602	2.5	3.21	16	9.32	27.93	.676	.349	.2725	40.31
606	2.0	2.71	60	18.06	45.69	1.113	1.106	.816	73.31
602	1.75	2.46	105	23.90	54.89	1.72	1.760	1.25	72.67
600	1.5	2.21	140	27.59	56.93	2.20	2.110	1.429	64.95
590	1.25	1.96	170	30.41	55.65	2.53	2.27	1.45	57.31
600	1.0	1.71	270	38.32	61.18	3.43	3.14	1.84	53.64
620	.85	1.56	378	45.34	66.04	4.43	4.01	2.18	49.21
"	.75	1.46	400	46.64	63.57	4.68	3.97	2.05	43.80
"	.60	1.31	505	52.41	64.11	5.06	4.50.	2.06	40.71

No. 8.

Helix: 24 part commutator, 336 convolutions, 2.5 m.m. wire, .4014 S. U. resistance.
Electro-magnets: 512 convolutions, 5.5 m.m. wire, .3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended.	Total developed.	Developed in outer circuit.	
715	4.5	5.21	..	..	..	.365	..	..	..
698	3.5	4.21	4	4.66	18.32	.427	.114	.095	22.25
700	3.0	3.71	21	10.69	37.03	1.43	.530	.429	30.00
710	2.5	3.21	50	16.49	49.42	1.59	1.09	.682	42.89
680	2.0	2.71	105	23.91	60.50	2.64	1.94	1.43	54.16
690	1.75	2.46	165	29.96	63.11	3.94	2.76	1.98	50.25
708	1.5	2.21	210	33.80	69.75	3.90	3.16	2.14	54.87
685	1.25	1.96	270	38.32	70.13	4.47	3.60	2.30	51.45
686	1.0	1.71	380	45.46	72.58	5.04	4.42	2.59	51.29
730	.85	1.56	550	54.69	79.06	6.46	5.14	3.18	49.22
"	.75	1.46	620	58.07	79.16	6.76	6.16	3.16	46.74
"	.60	1.31	680	60.83	74.41	7.05	6.07	2.78	39.43
"	.50	1.21	900	69.97	79.05	7.72	7.42	3.06	39.63

No. 9.

Helix: 24 part commutator, 336 convolutions, 2.5 m.m. wire, .4014 S. U. resistance.
Electro-magnets: 512 convolutions, 5.6 m.m. wire, .3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended.	Total Developed.	Developed in outer circuit.	
450	1	1.71	100	23.33	37.24	1.56	1.16	.681	43.65
500	"	"	145	28.08	44.84	2.14	1.69	.987	46.12
550	"	"	190	32.14	51.32	2.69	2.21	1.29	47.95
600	"	"	235	35.75	57.08	3.43	2.73	1.60	46.65
650	"	"	290	39.72	63.42	4.24	3.37	1.97	46.46
700	"	"	360	44.25	70.65	5.00	4.18	2.45	49.00
750	"	"	420	47.80	76.32	5.81	4.89	2.86	49.22
800	"	"	490	51.63	82.44	6.86	5.70	3.34	48.69

No. 10.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.
Electro-magnets: 3200 convolutions, 2.8 m.m. wire, 7.563 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
502	∞	7.8	13	13	..	8.41	8.41	..	61.25	1.33	.69	..	..
513	12.0	4.87	30	12	5	12.77	8.08	5.21	58.07	1.47	.994	.409	27.82
517	10.0	4.54	35	12	7	13.80	8.08	6.17	58.50	1.58	1.082	.476	30.12
520	9.0	4.34	42	12	9	15.11	8.08	7.0	61.23	1.59	1.251	.552	34.72
498	7.5	3.99	40	10	10	14.75	7.37	7.37	54.95	1.42	1.086	.510	35.90
501	6.0	3.51	42	8	15	15.11	6.60	9.03	50.36	1.53	1.020	.612	40.00
500	4.5	3.05	50	7	22	16.49	6.17	10.94	46.96	1.53	1.038	.674	44.05
510	3.5	2.62	75	7	35	20.20	6.17	13.8	49.41	1.77	1.338	.834	47.12
502	3.0	2.38	82	6	42	21.12	5.71	15.11	46.93	1.74	1.329	.857	49.25
507	2.5	2.11	90	6	50	22.12	5.71	16.49	43.58	1.86	1.292	.851	45.75
502	2.0	1.81	120	6	85	25.55	5.71	21.5	43.18	1.95	1.479	1.11	56.92
495	1.75	1.65	140	6	95	27.59	5.71	22.73	42.5	1.92	1.572	1.13	58.85
492	1.5	1.48	160	5	110	29.50	5.21	24.46	40.77	2.01	1.612	1.12	55.72
504	1.25	1.30	190	4	140	32.14	4.66	27.59	39.01	2.16	1.681	1.19	55.09
506	1.1	1.19	205	4	157	33.39	4.66	29.21	37.12	2.27	1.661	1.16	51.10
512	1.0	1.11	200	4	155	32.98	4.66	29.03	34.18	2.09	1.511	1.05	50.23
505	.85	.998	225	4	180	34.98	4.66	31.30	32.60	1.96	1.528	1.04	53.06
510	.75	.917	220	4	183	34.60	4.66	31.55	29.63	1.87	1.374	.934	49.95
507	.6	.790	160	3	120	29.50	4.04	25.55	21.77	1.45	.861	.490	33.79

No. 11.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.
Electro-magnets: 3200 convolutions, 2.8 m.m. wire, 7.563 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
598	.3	.52	3	1	3	4.04	2.33	4.04	1.962	.24	.0106	.00613	2.554
596	.4	.61	4	1	3	4.66	2.33	4.04	2.655	.24	.0166	.00817	3.404
612	.5	.70	30	1	26	12.77	2.33	11.89	8.34	.375	.143	.0884	23.57
"	.6	.79	180	2	..	31.30	3.30	..	23.08	.87	.968	..	..
620	.6	.79	215	2	180	34.20	3.30	31.30	25.23	1.77	1.16	.736	41.58
615	.7	.87	280	3	240	39.03	4.04	36.14	31.71	2.26	1.66	1.14	50.44
"	.75	.917	300	4	250	40.40	4.66	36.88	34.59	2.51	1.87	1.28	51.50
600	.85	.998	290	4	245	39.72	4.66	36.50	37.02	2.571	1.97	1.42	55.25
612	1.0	1.11	305	6	235	40.73	5.71	35.75	42.21	2.87	2.30	1.60	55.74
"	1.25	1.30	290	7	210	39.73	6.17	33.80	48.22	2.86	2.56	1.80	62.93
598	1.5	1.48	230	8	160	35.37	6.60	29.50	48.88	2.81	2.32	1.63	58.00
615	2.0	1.81	195	10	120	32.57	7.34	25.55	55.05	2.89	2.40	1.63	56.40
620	3.0	2.38	130	12	65	26.58	8.08	18.80	59.07	2.66	2.10	1.33	50.00
625	4.5	3.05	85	14	32	21.50	8.88	13.19	61.23	2.30	1.76	.98	42.61
"	6.0	3.59	70	15	22	19.51	9.03	10.94	65.40	2.16	1.71	.898	41.57
630	7.5	3.99	55	16	16	17.29	9.33	9.33	64.42	1.89	1.49	.817	42 22

No. 12.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.
Electro-magnets: 3200 convolutions, 2.8 m.m. wire, 7.563 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
700	7.5	4.01	80	18	18	20.86	9.89	9.89	78.10	2.57	2.18	.918	35.72
"	6.0	3.59	80	17	25	20.86	9.62	11.68	69.92	2.57	1.95	1.02	39.69
707	4.5	3.06	95	16	35	22.73	9.33	13.80	64.94	2.88	1.97	1.07	37.15
710	3.0	2.39	165	14	90	29.96	8.88	22.12	66.85	3.19	2.68	1.84	57.67
704	2.5	2.12	195	12	115	32.57	8.08	25.01	64.47	3.59	2.81	1.96	54.59
716	2.0	1.82	235	9	150	35.75	7.0	28.56	60.75	3.94	2.91	2.04	51.77
723	1.5	1.49	315	7	220	41.40	6.17	34.60	57.60	4.28	3.20	2.25	52.57
715	1.25	1.31	350	6	260	43.64	5.71	37.61	53.38	4.23	3.12	2.21	52.25
722	1.0	1.12	385	5	300	45.76	5.21	40.40	47.85	4.27	2.93	2.04	47.77
705	.75	.92	370	5	305	44.86	5.21	40.73	38.53	3.45	2.31	1.56	45.21
703	.60	.80	300	5	270	40.40	5.21	38.32	30.18	2.20	1.63	1.10	48.03
716	.50	.71	150	4	100	28.56	4.66	23.32	18.94	.292	.725	.34	11.64
710	.40	.62	7	1	7	6.17	2.33	6.17	3.571	.290	.295	.019	6.552

No. 13.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.
Electro-magnets: 3200 convolutions, 2.8 m.m. wire, 7.563 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
450	1.0	1.12	140	..	105	27.59	..	23.91	28.85	1.47	1.02	.715	48.63
500	"	"	185	..	150	31.72	..	28.56	33.16	1.94	1.41	1.02	52.57
550	"	"	250	..	195	36.88	..	32.57	38.56	2.47	1.91	1.33	53.85
600	"	"	325	..	260	42.05	..	37.61	43.97	3.06	2.48	1.77	57.84
650	"	"	400	..	305	46.64	..	40.73	48.77	3.71	3.05	2.08	56.06
700	"	"	470	..	350	50.56	..	43.64	52.87	4.43	3.58	2.38	53.72
750	"	"	530	..	395	53.69	..	46.35	56.14	5.20	3.91	2.69	51.73
800	"	"	640	..	460	58.98	..	50.03	61.69	5.88	4.86	3.13	53.23
850	"	"	700	..	510	61.69	..	52.66	64.51	6.42	5.33	3.47	54.05
900	"	"	785	..	570	65.33	..	55.67	68.31	6.98	5.98	3.88	55.59
850	"	"	700	..	505	61.69	..	52.41	64.51	6.42	5.33	3.44	53.58
800	"	"	600	..	440	57.12	..	48.92	59.73	5.71	4.57	2.99	52.36
750	"	"	510	..	372	52.66	..	44.98	55.07	4.90	3.89	2.53	51.63
700	"	"	440	..	330	48.92	..	42.37	51.15	4.14	3.35	2.25	54.35
650	"	"	350	..	270	43.64	..	38.32	45.63	3.45	2.67	1.84	53.33
600	"	"	285	..	220	39.47	..	34.60	41.27	2.82	2.18	1.5	53.19
550	"	"	240	..	180	36.14	..	31.30	37.79	2.24	1.83	1.23	54.91
500	"	"	180	..	135	31.30	..	27.09	32.73	1.73	1.37	.918	53.06
450	"	"	135	..	100	27.09	..	23.32	28.33	1.28	1.03	.681	53.20

No. 14.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.
Electro-magnets: 2240 convolutions, 3 m.m. wire, 4.46 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
505	.8	4.70	23	23	..	11.19	11.19	..	49.01	1.34	.736	..	..
510	7.0	2.96	55	..	9	17.29	..	6.99	47.79	1.77	1.11	.428	24.18
502	6.0	2.8	60	..	12	18.06	..	8.08	47.21	1.74	1.14	.490	28.16
502	5.0	2.6	65	18	14	18.80	9.89	8.88	45.64	1.74	1.15	.493	28.33
492	4.5	2.48	65	16	16	18.80	9.33	9.32	43.53	1.71	1.10	.489	28.60
"	3.0	2.03	120	15	40	25.55	9.03	14.75	48.43	1.71	1.66	.817	47.78
515	2.5	1.84	125	14	53	26.07	8.88	16.98	44.79	1.99	1.57	.902	45.32
494	2.0	1.62	145	13	7	28.08	8.40	19.51	42.47	1.91	1.60	.953	49.39
"	1.5	1.36	180	10	100	31.20	7.37	23.32	39.75	2.01	1.67	1.02	50.74
508	1.25	1.22	210	..	130	33.80	..	26.58	38.50	2.18	1.74	1.10	50.46
512	1.0	1.06	260	9	170	37.61	6.90	30.41	32.73	2.40	1.65	1.16	48.33
515	1.0	1.06	280	..	180	39.03	..	31.30	38.65	2.41	2.02	1.23	51.03
506	.9	.99	295	..	205	40.06	..	33.39	36.93	2.37	1.98	1.25	52.74
515	.8	.92	220	7	220	34.60	6.17	34.60	29.72	2.52	1.38	1.20	47.61
"	.7	.84	295	..	222	40.06	..	34.75	31.42	2.52	1.69	1.05	41.67
498	.3	.52	95	2	75	22.73	3.29	20.20	11.04	0.71	.336	.153	21.55
510	.6	.77	280	5	200	39.03	5.21	32.98	28.06	2.18	1.47	.817	37.48
"	.5	.69	275	..	210	38.68	..	33.80	24.92	2.42	1.29	.715	29.54

No. 15.

Helix: 24 part commutator, 312 convolutions, 2.8 m.m. wire, .234 S. U. resistance.
Electro-magnets: 2240 convolutions, 3 m.m. wire, 4.46 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
700	..	.24	..	..	..	..	..	..	..	.28	..	..	..
"	.1	.34	2	..	..	3.29	..	..	1.044	.28	.0046	..	..
"	.2	.43	3	..	..	4.03	..	..	1.617	.28	.0087	..	..
712	.3	.52	14	..	10	8.88	..	7.37	4.311	.29	.0513	.0204	7.034
698	.4	.61	15	..	12	9.03	..	8.07	5.143	.28	.0622	.0326	11.64
712	.5	.69	370	4	305	44.86	4.66	40.73	28.89	2.61	1.74	1.04	39.84
715	.6	.77	510	6	370	52.66	5.71	44.86	37.86	3.50	2.67	1.51	43.14
"	.75	.88	570	..	360	55.67	..	44.25	45.74	4.08	3.41	1.83	44.85
720	1.0	1.06	630	15	325	58.69	9.03	42.69	53.14	4.10	3.82	2.28	55.61
714	1.25	1.32	440	18	260	48.93	9.89	37.61	55.73	4.08	3.66	2.21	54.16
708	1.5	1.36	410	21	215	47.23	10.69	34.20	59.97	4.05	3.80	2.20	54.32
700	2.0	1.62	325	25	150	42.05	11.68	28.56	63.60	4.00	3.58	2.04	51.00
712	3.0	2.03	230	32	80	35.37	13.19	20.86	67.04	3.48	3.18	1.63	46.83
"	∞	4.7	..	50	..	..	16.65	..	..	2.47	..	..	..

No. 16.

Helix: 24 part commutator, 288 convolutions, 3 m.m. wire, .173 S. U. resistance.
Electro-magnets: 3916 convolutions, 2.5 m.m. wire, 11.26 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
612	0.0	..	..	..	..	..	..	..	..	.25	..	..	..
640	.25	.418	..	..	..	..	..	..	..	.25	..	..	..
625	.5	.652	4	..	..	4.66	..	..	2.84	.25	.018	..	..
620	.75	.876	97	..	90.0	22.97	..	22.12	18.8	.76	.579	.46	60.6
630	1.0	1.09	220	2.0	190.0	34.6	3.3	32.14	35.21	2.44	1.63	1.29	52.86
630	1.25	1.29	225	3.0	190.0	34.98	4.04	32.14	41.13	2.57	1.93	1.61	62.64
635	1.5	1.5	205	3.5	170.0	33.39	4.36	30.41	46.76	2.59	2.09	1.73	66.79
636	1.75	1.69	185	3.5	145.0	31.72	4.36	28.08	50.05	2.46	2.13	1.73	70.32
638	2.0	1.87	165	4.0	120.0	29.96	4.66	25.55	52.3	2.47	2.10	1.63	65.99
628	4.5	3.38	68	6.0	32.0	19.23	5.71	13.19	60.60	2.05	1.56	.98	47.86
624	6.5	4.29	42	7.0	15.0	15.11	6.16	9.03	60.52	1.91	1.22	.66	34.55
635	9.0	5.17	32	7.5	8.5	13.19	6.39	6.8	63.67	1.81	1.13	.521	28.78
610	11.0	5.73	25	7.0	7.0	11.68	6.16	6.16	62.49	1.62	.98	.522	32.22
614	∞	11.43	8	8.0	..	6.6	6.6	..	70.43	1.25	.623	..	..

No. 17.

Helix: 24 part commutator, 288 convolutions, 3 m.m. wire, .173 S. U. resistance.
Electro-magnets: 3916 convolutions, 2.5 m.m. wire, 11.26 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
665	.25	.42	3	..	3	4.04	..	4.04	1.58	.271	.0085	.0051	1.82
670	.5	.652	30	..	28	12.77	..	12.34	7.74	.547	.132	.095	17.37
665	.75	.875	245	2.0	225	36.50	3.3	34.98	29.85	2.04	1.45	1.14	55.88
660	.85	.963	255	2.5	235	37.25	3.69	35.75	33.49	2.29	1.67	1.36	59.38
640	1.0	1.09	290	3.0	260	39.72	4.04	37.61	40.42	2.61	2.15	1.77	67.81
645	1.1	1.17	272	3.0	230	38.47	4.04	35.37	42.02	2.63	2.17	1.72	65.40
650	1.25	1.29	250	3.5	205	36.88	4.36	33.39	44.42	2.65	2.2	1.74	65.66
645	1.4	1.42	235	4.0	185	35.75	4.66	31.72	47.39	2.63	2.27	1.76	66.92
650	1.5	1.5	228	4.0	180	35.22	4.66	31.3	49.33	2.52	2.33	1.84	73.01
660	1.75	1.69	200	4.5	153	32.98	4.94	28.84	52.04	2.56	2.3	1.82	71.09
660	2.0	1.87	180	5.0	145	31.3	5.21	28.08	54.65	2.42	2.29	1.97	81.40

No. 18.

Helix : 25 parts commutator, 278 convolutions, 3 m.m. wire, .173 S. U. resistance.
Electro-magnets : 3,916 convolutions, 2.5 m.m. wire, 11.26 S. U, resistance.

Revolutions per minute.	Resistance in S.U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
817	1.1	1.17	435	..	360	48.65	..	44.25	53.15	4.67	3.47	2.69	57.6
812	1.0	1.09	465	..	385	50.29	..	45.76	51.11	4.81	3.44	2.61	54.26
815	1.25	1.29	405	5.0	335	46.94	5.21	42.69	56.53	4.82	3.56	2.85	59.12
820	1.5	1.5	370	5.5	290	44.86	5.47	39.72	62.83	4.85	3.78	2.96	61.03
814	1.75	1.69	330	..	250	42.37	..	36.88	66.85	4.82	3.8	2.98	61.82
812	2.0	1.87	300	..	220	40.40	..	34.6	70.54	4.64	3.82	3.00	64.65
824	.9	1.01	450	..	385	49.47	..	45.76	46.65	4.71	3.09	2.36	50.10
820	.8	.92	450	..	390	49.47	..	46.06	42.56	4.35	2.82	2.12	48.73
808	.75	.876	430	..	390	48.36	..	46.06	39.55	4.12	2.56	1.99	48.30
840	.6	.743	220	..	215	34.60	..	34.2	24.00	2.4	1.11	.878	36.58
830	.5	.652	..	..	100	..	..	23.32	..	2.37	..	.34	14.34
820	.5	.652	75	..	70	20.20	..	19.51	12.30	2.34	.333	.238	10.16

No. 19.

Helix : 24 part commutator, 288 convolutioos, 3 m. m. wire, .173 S. U. resistance.
Electro-magnets : 3916 convolutions, 2.5 m. m. wire, 11.26 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
480	1.0	1.091	98		85	23.09	..	21.5	23.53	1.37	.728	.578	42.19
530	"	"	135		123	27.09	..	25.86	27.60	1.73	1.00	.837	48.38
602	"	"	223	..	195	34.83	..	32.57	35.49	2.33	1.66	1.33	57.08
670	"	"	290	..	250	39.72	..	36.88	40.47	3.14	2.15	1.7	54.14
744	"	"	390	..	320	46.06	..	41.72	46.93	3.95	2.89	2.18	55.19
800	"	"	455	..	380	49.75	..	45.46	50.70	4.73	3.38	2.59	54.76
864	"	"	515	..	430	52.92	..	48.36	53.92	5.64	3.82	2.93	51.95
911	"	"	585	..	490	56.42	..	51.63	57.49	6.92	4.35	3.34	52.85

No. 20.

Helix : 24 part commutator, 288 convolutions, 3 m.m. wire, .173 S. U. resistance.
Electro-magnets : 3,200 convolutions, 2.8 m m. wire, 7,563 U. S. resistance.

Revolutions per minute.	Resistance in U.S.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	Outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
716	∞	7.74	26	26.0	..	11.89	11.89	..	85.93	2.04	1.37	..	..
710	2.0	1.75	300	15.0	195	40.4	9.03	32.57	66.01	3.62	3.57	2.66	73.48
706	1.75	1.59	320	13.5	220	41.72	8.57	34.6	61.93	3.74	3.46	2.62	70.05
718	1.5	1.42	360	12.0	255	44.25	8.08	37.25	58.66	3.96	3.48	2.61	65.91
710	1.25	1.25	395	9.0	290	46.35	6.99	39.72	54.10	4.06	3.36	2.47	60.84
708	1.0	1.06	445	7.0	340	49.21	6.16	43.01	48.70	4.04	3.21	2.31	57.18
714	.95	1.02	460	6.0	360	50.08	5.71	44.25	47.65	3.79	3.2	2.33	61.47
706	.9	.977	460	..	370	50.03	..	44.86	45.64	3.75	3.19	2.27	60.53
710	.8	.896	460	5.0	380	50.23	5.21	45.46	41.85	3.62	2.81	2.07	57.18
714	.7	.814	445	4.0	375	49.20	4.66	45.16	37.40	3.35	2.47	1.78	53.13
715	.6	.729	390	..	340	46.06	..	43.01	31.35	2.77	1.94	1.39	50.18
715	.5	.642	..	..	230	..	..	35.37	..	..	..	.873	..
710	.5	.642	205	..	195	33.39	..	32.57	20.02	1.3	.896	.665	51.15

No. 21.

Helix: 24 part commutator, 288 convolutions, 3 m m. wire, .173 S. U. resistance.
Electro-magnets: 3200 convolutions, 2.8 m.m. wire, 7.563 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current on webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	Outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
468	1.0	1.06	170	..	130	30.41	..	26.58	30.10	1.34	1.23	.884	65.97
532	"	"	235	..	185	35.75	..	31.72	35.38	1.96	1.69	1.26	64.21
610	"	"	310	..	240	41.06	..	36.14	40.64	2.61	2.24	1.64	62.83
678	"	"	365	..	290	44.56	..	39.72	44.10	3.32	2.63	1.98	59.64
716	"	"	430	..	335	48.36	..	42.68	47.86	3.79	3.10	2.28	60.16
788	"	"	510	..	385	52.66	..	45.76	52.12	4.35	3.67	2.63	60.46
860	"	"	620	..	430	57.14	..	48.36	56.55	5.08	4.33	2.93	57.68

No. 22.

Helix: 24 part commutator, 288 convolutions, 3 m.m. wire, .173 S. U. resistance.
Electro-magnets: 2556 convolutions, 3 m.m. wire, 4.46 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
690	∞	4.63	46	46	..	15.82	15.82	..	68.4	2.67	1.45	..	..
702	2.0	1.55	300	24	155	40.4	11.43	29.03	58.47	4.01	3.16	2.11	52.62
694	1.75	1.43	300	22	170	40.4	10.94	30.41	53.94	3.97	2.92	2.03	51.13
698	1.5	1.29	335	20	205	42.69	10.43	33.39	51.42	3.99	2.94	2.09	52.38
696	1.25	1.15	390	18	245	46.06	9.9	36.50	49.46	4.12	3.06	2.08	50.48
696	1.0	.99	395	14	265	46.35	8.88	37.97	42.85	3.98	2.67	1.8	45.22
690	.9	.92	390	9	290	46.06	6.99	39.72	39.56	3.52	2.44	1.78	50.57
649	.8	.85	385	8	290	45.75	6.6	39.72	36.32	3.39	2.22	1.58	46.61
706	.7	.78	360	7	270	44.25	6.16	38.32	32.14	3.02	1.9	1.29	42.71
684	.6	.702	290	..	245	39.72	..	36.50	26.02	2.65	1.38	1.0	37.73
684	.5	.623	..	..	160	..	..	29.50	..	1.26	..	.544	43.18
684	.5	.623	140	..	..	27.59	..	..	16.05	1.26	.594	..	..

No. 23.

Helix: 24 part commutator, 288 convolutions, 3 m.m. wire, .173 S. U. resistance.
Electro-magnets, 2556 convolutions, 3 m.m. wire, 4.46 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse power.			Percentage of energy turned into useful work.
	Outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
492	1	.99	240	7.0	160	36.14	6.16	29.5	33.41	2.11	1.62	1.09	51.66
528	"	"	282	9.0	185	39.17	6.99	31.72	36.21	2.48	1.9	1.26	50.81
602	"	"	345	12.0	235	43.31	8.08	35.75	40.04	3.07	2.32	1.6	52.12
634	"	"	410	14.0	280	47.23	8.88	39.08	43.66	3.61	2.76	1.9	52.63
722	"	"	450	16.0	300	49.47	9.33	40.4	45.73	4.27	3.03	2.04	47.78
790	"	"	540	18.5	335	54.20	10.03	42.69	50.10	5.0	3.64	2.28	45.60
856	"	"	610	21.0	370	57.60	10.69	44.86	53.24	5.76	4.11	2.52	43.74

ON THE PROBABLE DURATION OF IRON STRUCTURES.

By DR. H. FRITZSCHE.

From Mittheilungen des Sächsischen Ingenieur-und Architekten-Vereins, for Abstracts of papers of the Institution of Civil Engineers.

ATTENTION was first drawn to this subject at a sectional meeting of the German Engineering Union in 1873, and reports were invited from the Saxon and Hanoverian Societies. On behalf of the latter, Herr Launhardt expressed the opinion that the failure of iron structures is caused, not so much by molecular changes and loosening of rivets, as by rust, and that scarcely perceptible deformation would take place beforehand.

The Hamburg Society mooted the idea that the question of duration was one with that of resisting power, and that uniformly repeated observations might therefore be replaced by periodic load tests.

The Berlin Architects' Society recommended the division of observations into special and general; the latter to embrace: 1. Measurement of permanent deflection; Measurement of deflection under a load; 3. Enumeration of constructional pieces and rivets already repaired; 4. Examination of any existing looseness of the connections at points of junction; 5. Examination of the paint and any existing rusted places. The special observations were to supplement the general and to embrace measurement of; 6. the deflection of the lower boon under a moving load; 7. the distance between upper and lower booms; 8. the lengths of diagonals; 9. horizontal swinging in the middle of the girder. It was added, that (*a*) for each structure a special observation book must be drawn up; (*b*) the general observations should be repeated quinquennially, the special once a year; (*c*) all observations, where possible, should be made by the same observer; (*d*) repairs to important parts of the structure, and the soundness of the material as well as of the connections, should be carefully examined.

From the various suggestions received the author has drawn up a scheme of notes to be made.

For bridge girders, two tables, one for permanent, the other for elastic bending, are given with vacant spaces for the insertion of—date of observation; temperature and state of the weather; the position of the marks

$$a,\ b,\ c,\ \Big(\overbrace{<\frac{E}{2}\times\frac{E}{2}>}^{d}\Big)$$

$$\underset{a}{}\quad\underset{b}{}\quad\underset{c}{}$$

on the under, and of *d* on the upper, boom of a girder for a length E with reference to

{ their original ordinates;
{ " ordinates after permanent bending;

the measured

{ permanent deflection $b-\frac{a+c}{2}$;
{ elastic " " ;

the relative { permanent deflection.
{ elastic "

The ordinates *a*, *b*, *c*, *d*, and the length E, are to be measured in millimeters before the erection. - The measurements with reference to permanent bending are to be made on each occasion before bringing on and after removing the trial load; those relating to elastic bending are to be made with the load on, and, 1, at rest; 2. moving at the rate of 10 meters per second. A space is also provided for remarks on the measuring instruments used, repairs carried out, the rivets, rust removed, renewed paint, &c. It is added that a considerable alteration in any measurement will point to the necessity of calling in an expert to discover the weak point.

With reference to iron constructions in general, it is noted that the task of making frequent observations on structures easily accessible to them should be remitted to specialists.

REPORTS OF ENGINEERING SOCIETIES.

ENGINEERS' CLUB OF PHILADELPHIA.—December 3d, 1881. This meeting was the first held in the new rooms, although they were only partially ready for occupancy.

Officers were nominated to serve during the year 1882.

The matters of scientific interest presented, were as follows:

Mr. John E. Codman exhibited drawings of and described Nicholson's Fire Escape, which consists of a fire-proof brick tower, octagonal externally and cylindrical internally, with central shaft about 18 inches diameter, around which is formed a winding passage, of a U shaped section, 2 ft. 3 in. in width, with smooth or glazed surface, and inclined at angle of 35°, with retarding curves of less gradient. Fire-proof doors would connect with each floor and roof, and a vestibule with the surface of the ground below. It is intended that those escaping shall assume a sitting posture on entering the spiral and slide to the bottom, and it is claimed to be safer than other escapes for those unaccustomed to ladders, or weakened by fright or excitement.

Mr. Codman also exhibited a working model of Deschamp's Angular Shaft Coupler, by means of which shafting can be offsetted when bearings are displaced or bent to any angle, from 0° to 90°.

Prof. L. M. Haupt exhibited an Interpolating Scale, devised by Prof. W. S. Chaplin, of University of Tokio, Japan, by means of which any intermediate point of elevation between two known points, on a topographical plan, can be readily determined.

He also read a short discussion of Mr. S. C. Gant's scheme of Underground Railroads in Philadelphia, presented at last meeting. Prof. Haupt while decidedly favoring rapid transit and admitting the practicability of the construction proposed, considers Mr. Gant's estimate of the cost entirely too low, and, by comparison with the Union Tunnel at Baltimore, he estimates that that portion of the tunnel system which Mr. Gant estimates at $1,733,710 would cost $6,05 1,500, or about three and one-half times the original estimate, and even this he considers too low for the plan proposed.

Prof. Haupt also read a paper upon Railroad Cross-ties, touching especially upon the desirability of an iron tie, a model of which he exhibited at the last meeting.

Mr. T. Earl Collins exhibited and described a model of the Camerer Valve Motion.

Mr. Wilfred Lewis exhibited a movable head T square, the head of which is held very firmly in position by means of a cone clutch.

Mr. Howard Murphy opened the proposed discussion upon Passenger Elevators, by reading an account of the means and results of testing wire ropes and methods of attachment to cages, by Herr Baumann.

ENGINEERING NOTES.

A NEW METHOD OF COMMUNICATING WITH WRECKED VESSELS.—Messrs. Low and Duff, engineers, Dundee, have just made an important improvement in connection with apparatus for communicating with wrecked vessels. It is a new gun which they tried at Monifieth recently with marked success. The gun is 2 ft. long, with a bore of 2¼ in., and it is so constructed that the line which is to be fired from it passes through the back end of the gun. In the experiments which were made the line was shot 400 yards with 2 ozs. of powder, which would have sent it further had the line used on the occasion been longer. The cord is coiled in the form of a cop and put inside of a steel canister. This canister is fired out of the gun, and leaves the line streaming behind it. The distance to be covered is simply a question of size of gun and canister. The gun was sent to Birmingham and tested in the most thorough manner in the proof-house there. The twine used in the experiment was made of flax, and carried 200 lbs. dead weight with a length of 6 ft. of twine.

PUMPING PETROLEUM.—It has for some years been the practice in the United States to transport crude petroleum by pumping it through long mains extending in some cases over hundreds of miles; but this system has not been established to any extent on the eastern side of the Atlantic. It is now, however, being carried out on an extensive scale in the Caucasus in South Russia, and Messrs. S. Owens and Co., of Whitefriars Street, have just completed an extensive pumping plant for this purpose. The plant consists of a number of small Blake pumps with 10 in. steam cylinders, 3½-in. pumps, and 12-in stroke, which will be used to deliver the oil through branch services into the tanks from which the main pumps draw. For the main oil line Messrs. Owens have constructed three pairs of duplex Blake pumps with a new arrangement of valve gear, the valve of one pump of each pair being moved by connection with the piston rod of the other pump, and *vice versa*. The pumps have 24-in. steam cylinders with 30-in. stroke, the piston rods being double, and giving motion through a strong crosshead to a pair of single-acting plunger pumps with 4½-in. rams of phosphor-bronze, these pumps being intended to deliver the oil against a pressure of 1,500 lbs. per square inch. The pump cylinders are of close-grained cast iron with removable liners of phosphor-bronze, and the valves are of gun metal with leather faces, and are guided by long spindles on their upper sides working in strong gun-metal caps. The plungers are packed by hydraulic leathers. The arrangement of valve gear for the steam cylinders is very simple, and works with great smoothness, as we had an opportunity of seeing a few days ago, when Messrs. Owens were testing one of these pair of pumps in steam. We propose to illustrate the arrangement in an early issue, but meanwhile we may say that each steam cylinder has five ports, the two outer ones at each end being for steam admission, and the two inner ones for the exhaust. The slide valves are of the ordinary D pattern, and cushioning valves are provided for determining the stroke of the pistons, which can be easily adjusted to suit the speed and pressure. The two pumping engines forming

each pair are mounted on massive cast-iron girder bedplates, the whole forming a thoroughly good and substantial job. The weight of each set of pumps complete is about 10 tons.

RAILWAY NOTES.

THE TRANS-CASPIAN RAILWAY.—It is reported at Baku that the military Trans-Caspian Railway is about to be purchased by a firm well known in the region of the Caucasus, which is already at the head of numerous industrial and commercial enterprises in that province. The line is completely finished for a distance of 217 versts up to its terminus, Kizil-Arvat, and trains have been running on it for some weeks. It will not be extended further, but it is in contemplation to establish a tramway as far as Bami, so that there will be only 180 versts of road left in order to reach Askhabad. This Road is passable for vehicles, and is divided into four stages, to each of which there is a fortified station-house, where the horses necessary for the service of the Government are kept.

PORTABLE MILITARY RAILWAYS.—We have more than once advocated the liberal use for military purposes of light portable lines of railway, which if properly constructed can be efficiently employed even in districts where it is difficult to make a good ordinary road, and under these circumstances we are interested in noticing that a railway of this kind has just been sent out to Tunis for the use of the French army in connection with their march to Kairouan. The line in question is of 0.60 meter (23.6 in.) gauge, and has been constructed by M. Decauville, whose establishment at Petit-Bourg has lately been kept going day and night to complete the 50 kilometers (31 miles) of permanent way required by the end of October. The weight of rails which have been selected by the Minister of War are 14.1 lbs. and 19.2 lbs. per yard, and in the construction of the permanent way M. Decauville has introduced an improvement in the connection of the lengths, which enables the curved portions of the line to be used either right or lefthanded at pleasure. The line, which M. Decauville has named the "military pioneer railway," will serve for the transport of water, food, and munitions, and for carrying the sick or wounded. A small locomotive, the "Kairouan," weighing 3 tons, is being provided for service at the harbor, and to facilitate the unloading of the vessels.

BRITISH RAILWAYS IN THE PAST AND PRESENT. — Attached to one of the balance-sheets of the Great Northern Railway there is a valuable comparative statement of the capital, revenue and other particulars of that railway over twenty half years. It becomes of interest, then, to trace the relative position of the railway so as to ascertain how the capital stands at the beginning and end of a decade; whether the line is as cheaply worked; and whether the invested capital is as productive. Broadly, it may be aid that ten years ago the capital of the Great Northern Railway was £19,876,000—or that part of it represented by shares and stock. In the total—with fixed charges added, that is—it was £22,300,000. It is now £33,970,000, so that there has been an increase, roughly, of fifty per cent. But the miles at work have not risen in like ratio—they were 491—they are now 601. And the gross receipts—£1,259,000 ten years ago, £1,664,000 now in the half year—have, it will be seen, increased much less than the fifty per cent. increase of the capital. On the other hand, the working expenses—£581,000 ten years ago, and £866,000 now—show an enlargement very close to that fifty per cent. which is that of the increase in the invested capital. In the last half of 1871 the working expenses were 46.13 per cent. of the earnings—in the last corresponding half year they were 52.06. For each train mile run the gross earnings were ten years ago 5.24s; but in the last comparative half-year they were only 4.52s. It is thus tolerably clear that the expenditure of capital in the ten years has not been so remunerative as before; and it is also plain that the working expenses have grown. It has to be borne in mind, in fairness, that there is a large amount of unproductive capital now, but so there would also be ten years ago. And, as the broad result, it is apparent that there has been a very great reduction in the dividends declared on the original capital—for that portion receiving fixed dividend has not had its rate affected of course. Hence it would appear that at the present time the Great Northern needs rest from heavy capital expenditure. It is only a type of several other railways which have expended large sums of money, but it is an emphatic type, for the dividends of few of the great companies have sunk so much in the decade as it has done. It is to be hoped that the completion of heavy works now progressing may enable the figures of future years to be more favorable.

ORDNANCE AND NAVAL.

THE NEW LYMAN-HASKELL CANNON. — The Lyman-Haskell accelerating or multi-charge cannon is made with a succession of cylindrical chambers called "pockets" below the bore whose axes point toward the muzzle of the gun and form with its axes angles of about 60 degrees. In these pockets are placed the accelerating charges or powder that ignite after the passage of the projectile, which is started by the explosion of the initial charge in the gun chamber, in the usual manner.

Col. J. H. Haskell, of New York, adopting the accelerating principle first introduced by A. S. Lyman, also of New York, the inventor of the "Lyman accelerating gun," has made a number of improvements on it which are now the property of these two gentlemen jointly with their assigns.

The new Lyman-Haskell gun is expected to throw a projectile four calibers in length a distance of ten or twelve miles, leaving the gun at a velocity of 4,000 feet per second, which, it is claimed, can be done without the danger of bursting the piece, which would occur if the

necessary force were generated by the explosion of a single charge

A number of tests of the principle have been made; notable among them are those at the Washington Navy Yard, where a 2½ inch accelerating gun was tested in competition with a 5-inch Whitworth (English) gun. The target consisted of 5 inches of iron plates backed with 18 inches of oak timber. At a distance of 200 yards, the projectile from the accelerating gun went entirely through this target and landed 100 yards beyond it, while the English projectile fired from the same distance, with double the charge of powder, failed to penetrate the same target. Gen. John Newton, U. S. Engineer, finds that a 10-inch accelerating gun will be as efficient as the 81-ton Armstrong, while a 12-inch accelerating gun will be more powerful than the 100-ton Armstrong.

On the 24th of October a casting was made at the "Scott Foundry" of the Reading Iron Company, for a 6-inch Lyman-Haskell gun. This casting is made without cores, and is to be bored for the pockets and will form the breech section of the gun. Its weight is upward of 50,000. It was cast from two reverberating furnaces charged with 56,000 pounds of cold-blast charcoal pig-iron of the following brands:

Brands.	No. 1 Furnace. Pounds.	No. 2 Furnace. Pounds.
Maiden Creek ...	3,680	2,745
Juniata.....	3,670	2,745
No. 2 Richmond..	15,425	11,555
Falling Spring and No. 1 Franklin	4,775	3,575
Remelted Iron....	4,545	3,400

The section to form the muzzle portion will be cast separately, and firmly joined by socket to the breech section. The whole is to be then lined with steel in one continuous cylinder for the bore and smaller ones for the pockets.

The weight of the gun when completed will be 25 tons, with a total length of 24 feet 11½ inches. It will have a bore of 6 inches, and will carry a ball weighing 150 pounds, of 4 calibers length. Eighteen pounds of hexagonal powder will be used in the breech, with 28 pounds of powder of finer quality in each of the four pockets, making a total of 130 pounds. This is one hundred pounds more of powder than is ordinarily used, and by means of this system of explosion, the projectile will have a penetrating power as 1½ is to 4, compared with other cannon. The initial velocity of the ball will be 4,000 feet in a second, while that of other guns is from 1,500 to 2,000. The ball is calculated to penetrate two feet of wrought iron at a distance of 200 yards. By means of the successive discharges of powder from the four pockets the pressure upon the ball will be maintained, thus giving it its great velocity, which will carry a ball twelve miles. The explosion takes place in tough steel, supported by the strongest cast iron. After its completion, which will be in several months, the gun will be taken to Sandy Hook, where it will be thoroughly tested in the presence of army officers and distinguished scientists.

HYDRAULIC MACHINERY ON BOARD SHIP. — Messrs. Brown, Bros. and Co., of Cannon Street and Edinburgh, have recently fitted up the steamship Quetta with the most elaborate and complete set of hydraulic machinery ever put into a ship. A pair of engines capable of working up to 100-horse power is employed to maintain a constant water pressure of 700 lbs. on the square inch, kept under a steam accumulator, and from the accumulator pipes are led to all parts of the ship where power is required, The Quetta belongs to the British India Line, and has a gross tonnage of 3,302 tons. On the forecastle is a 15 ton hydraulic capstan driven by four pendulous hydraulic cylinders, collectively of 50-horse power. A similar but less powerful capstan is placed at the other extreme end of the mains on the poop. The ship is steered from the bridge amidships by a wooden tiller similar to that of a small yacht. By moving the tiller, a slide valve is opened, which is in connection with the hydraulic rams and cylinders aft. When the valve is opened to either port or starboard cylinder, a corresponding movement of the rams and rudder takes place, strictly controlled, however, by mechanism, which prevents the helm from running away from the steersman. The rudder itself is connected with the rams in such a way that the latter obtain an increasing leverage as the rudder is being put hard over, when this leverage is, of course, most needed. A hydraulic cylinder with a similar arrangement of valve and automatic controlling levers is applied to the main engines, by which they can be reversed or stopped in three seconds by a single reversing lever. The water-tight door of the shaft tunnel is also opened and closed by a hydraulic cylinder, the valve of which is near the deck, so that in the event of an accident this door can be instantly closed. In the stokehole close by is fixed a hydraulic hoist for lifting the ashes. The most valuable application of the Quetta's hydraulic machinery is the loading and unloading of the cargo. It may be mentioned that at Colombo, in the course of the single voyage which the Quetta has already made to Calcutta and back, 1,250 tons of rice were discharged in ten hours. On the Quetta's deck there are four hatches Those at the extreme ends fore and aft are fitted with single hydraulic hoists, the two main hatches having double hydraulic hoists. Each of these hoists is capable of raising a ton and a half through a height of 70ft., at a speed of 5ft. per second. The hoist consists of hydraulic rams, fitted into cylinders, and working through stuffing boxes. Each ram is connected to three chain pulleys, while the other three are carried by the cylinder base-plate. A foot of rise in the ram raises the load 6 feet. The water is admitted to the cylinder by a slide-valve worked by a single lever, whereupon the load is lifted; while, by reversing the lever, the water is allowed to escape and the load to descend. An ingenious arrangement prevents the load from running from one extremity to the other, through the unskilfullness of the driver, and thus risk damage to the cargo. A wholly inexperienced man can thus work the

apparatus without any danger. The hoists will discharge cargo at the highest speed of 5ft. per second and be brought to a state of rest automatically at any position required. To summarize the advantages of the Quetta hydraulic machinery, a pair of engines in one place do, with no noise and half the consumption of fuel, the work usually performed by perhaps a dozen donkey engines; while about £30 or £40 a voyage is saved in wear and tear. The increase of speed obtained in loading and discharging cargo practically insures a quicker voyage. The rapidly-working machinery necessitates double gangs of men in the hold; but, though the hands are more numerous, they are paid for a shorter time; and the cost of labor per ton of cargo is thus less than usual. The prime outlay is considerably greater than under the ordinary system; but it is calculated that in at most three years the extra expense will have been saved.

THE dimensions of the new ironclads of which the Italian Admiralty have recently ordered the keels to be laid down within the month, one in the dock yardat Spezzia and the other at Venice, are as follows: Length, 100 meters; immersion, 7 meters 65 centimeters; displacement, 10,000 tons; engines, 10,000-horse power, giving a presumed velocity of sixteen miles per hour. The cuirass, which is to extend over a length of 55 meters, will be 45 centimeters thick and 40 at the bulwarks and turrets. The guns are to be of the kind which, three years hence, when the ships are ready for them, shall have been found by experience and experiment to be the most useful.

ON the afternoon of the 10th Nov. an iron screw steamer, the Zuid Holland, of 2,270 tons gross register and 220-horse power nominal, for the Rotterdam Lloyd's Mail Line between Holland and Java, was launched from the yard of Messrs. Raylton, Dixon, and Co. The dimensions of this vessel are: Length, 311ft.; breadth, 37t.; depth, 27ft. She is classed 100 A1 at Lloyd's, and will be fitted with cabin accommodation for first-class passengers in large deck-house, specially arranged for good ventilation and containing large saloon panelled in polished marble. This vessel is the sixth which has been built for the same line by Messrs. Rayhon, Dixon and Co., and is a sister-ship to the s.s. Utrecht, also trading between Rotterdam and Java.

GUNS VERSUS ARMOR.—A lecture on the above subject, but bearing the title of "The Attack of Armor-clad Vessels by Artillery," was delivered in the Theater of the Royal Artillery Institution, Woolwich, on October 19, by Captain C. Orde Browne, late Royal Artillery. General Sir Collingwood Dickson, V.C., K.C.B., presided, and there was a large attendance of naval, artillery and engineer officers and civil engineers. The lecturer pointed out the necessity for the recognition of the nature and thickness of an enemy's armor in order to decide whether to make the primary attack (*i.e.*, the attack on the armored structure containing the vital parts of the ship) or the secondary attack (*i.e.*, the attack on the less protected or unprotected parts). Dealing first with the primary attack, he showed that where steel was used as armor the blow was distributed through the mass of the steel, and therefore, that it had great power of resistance against a single blow, though it was liable to succumb to the continued fire, even of inferior guns; and he pointed out that this was not a question of penetration, but of shattering, the effect being probably proportioned to the stored-up work, irrespective of caliber. He showed that in compound or steel faced armor the effect was modified, and he mentioned the case of a compound target of Brown's, at present at Shoeburyness, which had resisted the fire of four rounds from 9-inch guns, and one from a 38-ton gun, three of the former containing the same amount of stored-up work as the single round from the latter gun; so that a sort of comparison became possible between the effects of a given quantity of work delivered in one heavy or three light projectiles. He said that while in the case of steel the blow was distributed through the mass, in the case of iron armor the iron suffered locally only, and hence it was either penetrated completely or was practically uninjured, and did not suffer seriously from the continued fire of guns unable to perforate it. Hence the great significance of the development of new type guns, steel shells, and gun-cotton charges. From the instance of the Krupp 9.45-inch 18-ton gun at Meppen, which perforated 20 inches of iron without injury to the projectiles, the lecturer deduced that fire might be carried into the most strongly-armed portion of any English armor-clad, except the *Inflexible*, by a new-type 18-ton gun. He showed how important it was to ascertain the limit of thickness of iron which any given gun may penetrate at any range, and gave the following rule for ascertaining it—viz., that a shot will penetrate armor one caliber thick for each 1,000 feet velocity. The results obtained by this rule were compared with those taken from Col. Inglis's diagram, and shown to be nearly approximate. With regard to "secondary attack," he referred to the case of the deck being struck from guns in positions of command, particularly in the case of ships engaging nearly head on, and pointed to the necessity for using common and shrapnel shell in attacking unprotected portions. The conning power and the funnel were dealt with under the head of "secondary attack." The case of the *Huascar* was referred to, it being noticed that her conning tower was destroyed, and the staff of the vessel killed. The vessel kept her stern, as being the weakest portion, out of fire as much as possible, and manœuvered so as to keep between the adversaries she endeavored to ram, and, generally speaking, showed great skill, except in the matter of her fire, for neither in her engagement with the English unarmored ships, nor afterwards with the two Chilian vessels, did she succeed in ever hitting anything to any purpose. With regard to the funnel, the lecturer pointed out that it afforded a natural mark for light guns, in the hope of reducing the steam-power of a ship.

The hopelessness of this endeavor was shown by calculating the effect of a funnel cut down from 50 feet to 30 feet, which would only result in reducing the speed one knot in 12. The lecturer then referred to different types of vessels, models of which he exhibited—viz., the *Glatton*, the *Inflexible*, the *Admiral Duperre*, and the *Polyphemus*, and showed the mode of attack in each case. As to ratio of weight of guns to tons of displacement, it was pointed out that the French ships have generally more pieces, and these of lighter weight, than the English, the average number of heavy guns in each of our first-class turret ships being 5.1, and in each first-class broadside 11.1, while in French first-class ships it is 15.3. The lecturer remarked that the total weight of metal in ordnance carried by each ship may be shown by the number of tons displacement per ton of gun—*i.e.*, English turret first-class, 56.1, broadside 43.5, French first-class 39.5, second class 52.3. The advantage of the all-round fire of the turrets might enable an English ship to bring a great weight of artillery into action, but it was a question whether the greater number of guns carried by broadside ships did not deserve more consideration than formerly, since the great development of power consequent on the introduction of new-type guns. Very heavy guns had special power against chilled-armor, which they might wreck in a way that would not be possible with the same power distributed among a number of lighter guns. This question concerned our navy more than our land artillery, seeing that the French, the Germans, the Russians, the Danes, the Dutch, the Spanish, and the Portuguese had forts of chilled iron on their coasts—a species of armor which England had not adopted, or even tried. To lead to discussion, the lecturer suggested two questions—first, whether we do not need medium new-type guns introduced as far as possible into the armaments of our ships and forts; and, second, whether the secondary attack of the weaker parts of armor-clad ships did not deserve more attention than it had hitherto received. The lecture was followed by a discussion.

BOOK NOTICES.

Publications Received.

Extra Census Bulletin—The Areas of the United States. Henry Gannett, E.M. Washington: Government Printing Office.

Dundee Street Railways, By Andrew Greig, M.I.C.E. Published by the Institution of Civil Engineers.

Report of Experiments on the Resistance of Thick Cast-iron Cylinders to Internal Pressure. By Colonel T. T. S. Laidley. Boston: Mills, Knight and Co.

Graphics of Rectangular Bridge Trusses. By Theo. Kandeler. Chicago. L. Schick.

Monthly Weather Review for October.

Elementary Lessons in Electricity and Magnetism. By Silvanus P. Thompson, B.A., F.R.A.S. London: Macmillan and Co. Price $1.25.

A new book on so important a topic by so eminent an authority will be welcome to a host of students. It is designed for the multitude of learners who are eager to find the logical connection between the teachings of the text-books in common use and the practical developments of electrical and magnetic science, which now occupy so large a share of the public attention.

How completely the author covers this important field of research, may be inferred from the following list of chapter headings:

I. Frictional Electricity.
II. Magnetism.
III. Current Electricity.
IV. Electro-statics.
V. Electro-magnets.
VI. Measurement of Currents.
VII. Heat, Light, and Work from Currents.
VIII. Thermo-Electricity.
IX. Electro-Optics.
X. Induction-Currents.
XI. Electro-Chemistry.
XII. Telegraphs and Telephones.
Appendix—Electrical Units and Exercises.

New System of Ventilation. By Henry A. Gouge. Fourth Edition, Enlarged. New York: D. Van Nostrand. Price $2.00.

The estimate of the previous editions of this work, which has led to a fourth one, is evidently based upon the thoroughly practical character of the author's suggestions.

The work is really a treatise upon one of the most important branches of sanitary engineering. Methods of replacing foul air by fresh air in all enclosed habitable places, as well as in all places designed for storage of perishable things are presented and urged as a necessary concomitant of an advance in civilization.

The essay is divided into two parts: Ventilation, Its Importance and Necessity; and What Is, and What Is Not Ventilation.

Report of the U.S. Commissioner of Education for the Year 1879. Washington: Government Printing Office.

This report is of interest chiefly to educators. It bears evidences of careful and laborious labor in compilation, and will be regarded with much interest by the few who are responsible for the methods of education, and will be kept for reference by many who have occasional use for statistics.

Sewer-Gases and How to Protect our Dwellings. By Adolfo de Varona, M.D. Second Edition Revised and Enlarged. New York: D. Van Nostrand. Price 50 cents.

That a second edition of this book should be so soon demanded is a natural result of the quality of the early edition and the public interest in so important a subject.

The author deals briefly and directly with the following topics :

Necessity of Sanitary Measures.
Sewer Gases.
Relation of Sewer Gases to Disease.
Sewers—Their Proper Size.
Inclination of Sewers.
Material of Sewers.
Ventilation of Sewers.
House Drains.
How Gases Enter the Dwelling.
How to Protect our Dwellings.
Subsoil Drainage.
Relations of Ground Water to Disease.
Ventilation of Dwellings.
Disinfectants.
The illustrations are numerous and good.

L'Astronomie Pratique et Les Observatoires en Europe et en Amerique. Par C. André et H. Angot. (Fourth Part). Paris : Gauthier-Villars. Price $1.50.

Something more than half of this little book is devoted to the meteorological stations of the United States. The remaining portion relates to the astronomical observatories of South America, of which and their equipments a brief descriptive account is given.

Dictionnaire des Arts, Manufactures et de L'Agriculture. Par Ch. Laboulaye. Paris. Price $43.20.

This extensive work fills four large volumes of about one thousand pages each.

The illustrations are very numerous and admirably adapted to the purpose of aiding in the description of processes and machines.

Important subjects are expanded to the magnitude of ordinary treatises. Thus "Filtration" covers sixteen pages and the steam engine seventy.

MISCELLANEOUS.

Celluloid may be used for preserving engravings, *clichés*, and stereotypes. The process employed for this purpose, we learn from *La Nature*, consists in taking an impression of the engraved block by means of a special cement, which receives the impression and rapidly hardens. The presses used to take the first impression are heated, and the sheet celluloid is then used to take the counter impression from which to print. Celluloid thus gives an exceedingly clear reproduction of specimens of lace and other fine work with difficulty obtained in any other way.

A method for determining the total solid matter in solution in different waters is described in the *Journal* of the Chemical Society, by Dr. Mills. The method is based on the fact that if a small glass bead with an attached weight is allowed to ascend in a saline solution of known strength, it will rise more slowly, the greater the amount of solvent present. Experiments are given showing that the rate of ascent is also dependent on the nature of the soluble matter, *i. e.*, on the viscosity of the solution. For detecting variations in the solids in the same water, for preparing standard solutions, &c., the bulb method is likely to be useful. Experiments detailed in the same paper lead Mills to regard the specific gravity of a potable water as a direct indication of the quantity of total solids in solution.

An electro-magnet of enormous dimensions has lately been made by Messrs. von Feilitzsch and Holtz for the university of Greifswald. The case is formed of twenty-eight iron plates bent into horseshoe shape, and connected by iron rings so as to form a cylinder 195 mm. in diameter. The height is 125 ctm.; the total weight 628 kilogs. The magnetizing helix consists of insulated copper plates and wires having a total weight of 275 kilogs. With fifty small Grove elements the magnet will fuse in two minutes forty grammes of Wood's metal in the Foucault experiment. The plane of polarization is rotated in flint glass after a single passage. The core of the largest magnet hitherto known, that of Plucker, weighed 84 kilogs. and the wire 35 kilogs.

Clerk's Gas-engine.—Hitherto gas-engines using compression before ignition have made at most one impulse for every two revolutions. It is evident that if an impulse could be obtained for every revolution a great increase of power would result. Many fruitless attempts have been made to accomplish this desirable end, which has, however, at length been effected in Clerk's gas-engine, which we illustrate on the next page. One of these engines is being exhibited at the Paris Electrical Exhibition by Messrs. Thomson, Sterne, & Co, of 9, Victoria Chambers, Westminster. This engine has a motor cylinder, 6 inches in diameter, and a light displacer cylinder of a larger diameter. The stroke of the piston is 12 inches, and it is connected to a crank by the usual rod. As the pressure in the displacer cylinder never exceeds 5 lbs. per square inch, the connections are very light, and it is driven from a pin on one of the fly-wheel arms. The displacer crank pin is in advance of the motor crank and at right angles to it. When it moves forward, the combustible mixture of gas and air is drawn into the displacer cylinder during the first half of the piston's stroke, at which point the gas is cut off and air only admitted for the remainder of the stroke. The displacer on its return stroke discharges its contents through a lift valve into the motor cylinder, the piston of which is hot at the out end of its stroke and has uncovered an annular port in the cylinder communicating with the exhaust pipe. The heated products of combustion discharge through this port until the pressure in the cylinder has fallen to that of the atmosphere. The air from the displacer then entering at the back end expels the remaining hot exhaust, and passes in part through the exhaust pipe. The cylinder is now filled with pure air, and when the combustible mixture enters, displacing in turn the air, the cylinder contains nothing but an ignitable mixture and air. The motor cylinder in its in-

stroke compresses the mixture into a space at the end of the cylinder, the pressure rising to 45 lbs. above the atmosphere, when ignition takes place, and the pressure now ranges from 200 to 250 lbs. per square inch above the atmosphere. The piston moving forward, the pressure gradually falls, and at the end of the stroke the exhaust discharges at about 30 lbs. above the atmosphere. This cycle of operations is repeated at every stroke. In larger engines the terminal pressure before exhausting is very much less than 30 lbs., being sometimes as low as 5 lbs. above the atmosphere; but this is obtained by an arrangement which allows of a greater expansion. The volume swept through by the displacer piston is greater than the combined volume of the motor cylinder and the space at the end of it, into which the ignitable mixture is compressed. As half of its charge is pure air, it follows that at every stroke of the engine the whole products of combustion are discharged and replaced by pure cool air before any combustible mixture is allowed to enter. This arrangement produces the greatest certainty in the action of the engine.

Premature ignitions sometimes arise from the combustible mixture entering the cylinder while it still contains products of the previous combustion, and being ignited at the wrong time, either by flame still existing in the cylinder, or by sparks on the walls of the combustion chamber, due to the ignited carbon from the decomposition of the oil used in lubricating. To prevent these irregular ignitions it is necessary to clear out any hot burned gases, and to secure a sufficiently low mean temperature of the surface of the cylinder and combustion chamber to render the existence of sparks impossible. In the engine under notice these conditions are secured by the use of the displacer cylinder, as the charge is not compressed in the cylinder, but merely passed into the motor cylinder at such a pressure above the atmosphere as is necessary to lift the valves and to discharge the exhaust. It therefore follows that it may be made of any size found necessary to pass the volumes of air for clearing and cooling. This device is the essential feature of the engine, rendering, as it does, an ignition at every stroke possible. The engine may thus be continuously worked up to its full power, igniting at every stroke without irregularity or stoppage. The arrangements for admitting gas and air, for cutting off the gas at the proper time, for igniting, and for exhausting, are of a simple and efficient character, and the engine is substantially made and well finished. We are informed that the engine exhibited at Paris gives 6-horse power by the brake at 145 revolutions, and indicates about 10-horse power. As the cylinder is only 6 inches in diameter, and the stroke 12 inches, it will be seen that this is a very powerful engine. It is, moreover, one which promises well to assist materially in the practical development of electric lighting.

As the result of an investigation of the statistics of the rate at which barometric changes traverse the British Isles, by Mr. G. M. Whipple, F.M.S., superintendent of the Kew Observatory, he concludes—(1) That the average rate of horizontal motion of barometric changes in their progress across the British Isles is about 53 miles per hour; (2) That the mean rate does not vary to any considerable extent from year to year; (3) That the maxima travel with somewhat greater velocity than the minima; (4) That the rate of horizontal motion is slightly diminished as the change passes northward. This is also proved by the fact that the mean velocity along the Valentia—Aberdeen, track, is slightly below that over the Falmouth—Leicester, track. By far the greater number of barometric changes traverse the country at rates between 30 and 60 miles per hour, but transits at the higher velocities are somewhat infrequent. The mean southwest-northeast velocity of 53 miles per hour, if resolved into north and south and east and west velocities by the ordinary method of the parellelogram of velocities, gives a resulting movement of 38 miles per hour in a west-east direction, which, he says, may be safely taken as the normal rate at which barometric changes traverse the British Isles.

The periodicity of rainfall formed the subject of an inquiry by Mr. G. M. Whipple, superintendent of the Kew Observatory, and by him a paper was communicated on the subject to the Royal Society early this year. From all the available statistics extending back with more or less completeness for many years, he finally deduced a table which shows that in no one case is there any indication of a period of any integral number of years from five to thirteen inclusive running through them. Hence, whatever period of variation in rainfall there may be, coincident with fluctuations in the spotted surface of the sun, either of ten, eleven, or twelve years, this method of treatment shows it to be completely masked—in a long series of observation—by other variations. The discrepancies exhibited in the first tables obtained made it very desirable to extend the field of inquiry, by including as many observations in the discussion as possible. Eventually he was able to collect ten series, which increased the total number of years of observations used in the discussion to 978. The result of the extended investigation in no way affected the conclusion pointed out by the observations previously treated—viz,, that taking the series of annual totals directly as they stand, there is no marked indication of the presence of a short cycle to be found. There are a few exceptions, in all of which cases the coincidences but slightly preponderate over the non-coincidences. Again, the curves of variation differ widely for the same epoch in localities comparatively close together.

Nickel was at one time deemed infusible, and at best only metalloid. It is many years since that its infusibility was conquered, and now pure nickel may be procured in almost any form. The latest achievement in this direction appears to be the successful reduction of iridium from its ores by Mr. John Holland, of Cincinnati. By mixing a certain percentage

of phosphorus with the ore, the metal can, according to a new American monthly magazine entitled *Progress of Science*, be melted and run into bars; the phosphorus can then be eliminated by heating the bars to a white heat in the presence of lime. The metal cannot be forged or filed into shape, but is cut with a revolving copper disc and emery and oil or water. Its use has been suggested as electrodes in lieu of carbon in the electric lamp.

THREE machines are exhibited in the Paris Exhibition which must be of great interest to all electricians, and which will hereafter be of historic importance. These are three magneto-electric machines, constructed by Professor Pacinotti, of the Cagliari University, and well known to fame by his invention of the ring-shaped armature as used in the Gramme and Brush machines. The first machine of this kind, made by Pacinotti at Pisa in 1860, is exhibited, as well as a second machine made by him in 1873. The second is a dynamo-electric machine in which a shunt is employed so that the current is divided between the fixed electromagnet and the resistance, two pairs of brushes making contact with the different segments of a commutator. The third machine exhibited was constructed in 1878 from a model made three years previously, and is a direct application of Arago's experiment showing the deflection of the magnetized needle by a revolving copper disc, the electric effect being derived from the induced current in the copper disc.

ACCORDING to MM. Behm and Wagner's *Bevölkerung der Erde*, Europe has now a population of 315,929,000 inhabitants; Asia, 834,707,000; Africa, 205,679,000; America, 95,405,000; Australia and Polynesia, 431,000; the Polar regions, 82,000; giving a total for the globe of 1,455,923,000, being an increase of 16,778,000 according to the latest known censuses. At the end of 1877 Germany had a population of 43,943,000; Austria and Hungary—1879—of 38,000,000; France—1876—of 36,900,000; Turkey in Europe, of 8,860,000; Russia, of 87,900,000. In Asia, China possesses 434,900,000 inhabitants; Hongkong, 134,144, Japan, 34,300,000; according to the census of 1878. The British possessions in India number 240,200,000 people—an estimate made before the census of this year—the French possessions 280,000; Cochin China, 1,600,000; the East India Islands 34,800,000; the islands of the South Sea, 878,-000. The area of Africa is estimated at 29,383,000 square kilometers, divided as follows:—Forests and cultivated land, 6,300,000; savannahs, 6,235,000; steppes, 4,200,-000; deserts, 10,600,000. The inhabitants of British North America number 3,800,000; of the United States, 50,000,000; of Mexico, 9,485,-000; and of Brazil, 11,100,000. The Polar regions extend around the Arctic circle with an area of 3,859,000 square kilometers, and the Antarctic regions about 600,000. The population of the former is small, with the exception of Iceland, which has 72,000, and Greenland 10,000.

AN extensive landslip has occurred on the side of the river Severn, at Broseley. One of the hills which border the river at this point has recently given away, falling towards the river, and carrying with it the Severn Valley Railway, which runs through the hill. Within a short period the railway has been lowered by the slip to the extent of five yards, thereby necessitating continual attention and expense on the part of the Great Western Railway Company in keeping up the level. The slip has now assumed a serious aspect, and at one point, near Jackfield, the river has been so narrowed by the fall of earth as to be scarcely navigable. The fall continues daily, and is placing in jeopardy the buildings upon the hill. With the view of taking immediate measures for preventing loss of life, or any further damage to property, a trial shaft has been sunk for the purpose of ascertaining the depth of the slip, and it is thought probable that a scheme may be adopted to prevent the slipping of the hill. A report upon a slip at this point was made to the House of Lords some time since. The slip is one hundred yards in breadth, and upon the land affected there is a church, as well as other buildings.

A BLOCK of stone, 65 ft. long, 30 ft. wide by 10 ft. thick, has been quarried on Spoon Island, Queens County, New Brunswick.

THE Phosphor-Bronze Company, Limited, has been awarded the highest order of merit and gold medal at the Adelaide Exhibition, for phosphor-bronze, and articles made therefrom.

THE engineer of Ottawa, has reported against the proposal to light the city by electricity. The present cost of doing so by gas is stated to be £2546. Electricity generated by steam would cost £4960, and, if water power were utilized, £3200.

AT the Nepean—Adelaide—Waterworks 350 men had, at receipt of last mail, struck for higher wages; they demanded 8s. per day, instead of 7s. 6d. they were receiving, and they also required two intervals during the day of a quarter of an hour each for smoking.

IT seems that the earthquake in the Abruzzi, was far more destructive than was at first thought. The Commission of Succor reports that of 1340 houses, seventy-nine must be rebuilt, and 618 have been rendered uninhabitable, so that about four-fifths of the population are without shelter.